2020
STATE AND FUTURE OF GEOINT
REPORT

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INTRODUCTION

This is the sixth edition of USGIF's annual State and Future of GEOINT Report.

We humans invented computers, improved them, and now we are imagining new, innovative ways to work productively with and alongside them. We increasingly recognize that the majority of jobs will be profoundly changed over the next decade, and we must continually reinvent ourselves to be best positioned to thrive in the new ecosystem. In this report, we seek to drive the evolution of the GEOINT profession and to better understand the underlying tradecraft that enables it.

We have a shared responsibility to understand where the internet, social media, and other fast-paced, enabling technologies are taking both us as individuals and our shared bureaucracies. We are in search of the opportunities to leverage various disciplines that can be useful to help drive synthesis and analysis to enable improved mission outcomes.

Our Foundation's focus on tradecraft has been paramount since our beginning. Tradecraft development helps to foster networking, communication, critical thinking, ethical judgment, collaboration, and the ability to apply knowledge in real-world settings. Importantly, it is dogs and cats working together, where we learn how to work and interact with people from different backgrounds, cultures, and belief systems. This year's articles are a testament to the power of diversity in our community. Our journey must incorporate the social, cultural, political, ethical, and aesthetic contexts that make us human and define how we prosper, live, work, and play with one another.

We work in a global industry leveraging the confluence of IT, defense, and commercial technologies. Each day we endeavor to understand the technology and its implementation to help empower its human counterparts. We have witnessed the power of digital mapping technology, we now take for granted the ease with which we integrate global information sources. Opportunity abounds—we humans and our machines are poised to open doors to new understanding—providing a decision framework that fully incorporates the agility of the technology and decision-making.

The State and Future of GEOINT Report is one of the Foundation's capstone projects. It is digested, downloaded, and discussed, generating an improved understanding of our ever-evolving profession. The report helps define and drive thought leadership to renew and extend the GEOINT discipline. Each year, through the lens of people, process, technology, and data, the report offers insights about the state and potential of our community and its tradecraft. This year's report demonstrates the power of collaboration across academia, industry, and government to make informed statements about the possible.

On behalf of USGIF members, academic affiliates, staff, and the Board of Directors, I want to thank the authors and their leadership who came together to help define the future and bring new ideas to fruition. This document stands to serve as a conversation starter for acceptance and debate. We must continue to collaborate on important efforts such as these to better understand the important advances across technology, tradecraft, and professional development in our GEOINT ecosystem.

Jeffrey K. Harris
Chairman, USGIF Board of Directors

⊕ Expanding the Utility and Interoperability of Rapidly Generated Terrain Datasets

By Jason Knowles, Ph.D., GISP, GeoAcuity; Col. [ret.] Steven D. Fleming, Ph.D., Spatial Sciences Institute, University of Southern California; Ryan McAlinden, Institute for Creative Technologies

Reality modeling is a staple in military modeling and simulation (M&S) communities. Whether from overhead or terrestrial imagery, photogrammetric-based collector's reality modeling advancements now allow for the generation of high-resolution 3D models from a variety of sources to rapidly meet M&S needs. The University of Southern California's Institute for Creative Technologies (ICT) Modeling and Simulation Terrain Team creates these immersive and informative 3D datasets that help warfighters and supporting elements improve performance through its participation in the U.S. Army's One World Terrain (OWT) effort. These high-resolution 3D models deliver enhanced real-world views and provide a detailed understanding of the physical environment, allowing for in-depth simulated mission rehearsal and planning. Traditionally, these models were designed to serve the needs of the M&S communities only, with no allowance for geospatial representation in place in space (i.e., single-scene viewing). The models were limited to training and theoretical/scenario-based mission planning. ICT, through its partnership with the University of Southern California's Spatial Science Institute (SSI) and GeoAcuity, a veteran-owned small business, has been working on an effort to transition and geospatially enable these datasets from M&S-specific needs to a more "operationalized" and interoperable dataset designed to better integrate with the GEOINT Community writ large. This has been done by a dynamic team with roots in both disciplines who conducted an in-depth study of the knowledge and technology gaps between the M&S and GEOINT Communities and the identification of the best way to ameliorate those differences. Through addressing differing data formats/standards and underlining how to best leverage geo-coordinates, data projections, and accuracy needs, this effort has allowed for the integration of these valuable, high-resolution datasets to be interoperable with both M&S software, commodity GEOINT, and operational mission command and mission planning systems.

Reality Modeling: Traditional Data Uses and OWT's Role

Reality modeling provides a detailed understanding of the physical environment, and geo-specific 3D terrain representation is revolutionizing the M&S world. In tandem with the increased availability and use of unmanned aerial systems (UAS) and small satellites, reality modeling advancements now allow for practitioners to generate high-resolution (~cm-level) three-dimensional models to meet M&S needs across all-terrain environments. Scalable, mesh-based models deliver enhanced, real-world visualization for a variety of purposes including training, simulation, rehearsal, intelligence, and operations. Many simulators and mission command systems today still rely on precision 2D geospatial data, though increasingly there is a requirement to incorporate true 3D data into the workflow, which enhances the realism and better represents the complexity of the operational environment. This requirement ranges from ground-based, dismounted operations through large-scale combined arms missions sets where having an accurate, geo-specific 3D representation of the surface is important.

OWT is part of the Army's Synthetic Training Environment (STE) program, which has a requirement to create the Army's next-generation M&S platform across a wide spectrum of mission sets and operations. The goal of OWT is to create a geo-specific, high-resolution 3D representation of Earth's surface that can be fed into the STE platform and delivered to the point-of-need. OWT relies on a cadre of traditional and non-traditional sources to produce this 3D representation; from open-source to commercial to national technical means. More specifically, OWT advances the feasibility of turning collected terrain data into simulation-usable terrain features that can be employed in near real time (and eventually in real time) by simulation platforms. This work demonstrates how rapid terrain generation may be incorporated in near real or real time into a virtual or constructive environment for geo-visualization and simulation applications.

Research has been conducted on the challenges presented by 3D terrain data for several decades, harkening back to the days of the Army's Topographic Engineering Center (TEC). In the Department of Defense (DoD), tremendous efforts have focused on building the Army's suite of next-generation interactive simulation and training platforms. Years ago, terrain was often considered the "Achilles' heel" of simulators. Its generation is time-consuming, expensive, manpower-intensive, and fraught with vagaries that result in unrealistic, unsatisfying, and often uncompelling synthetic experiences.

Simulation environments are often created with entities "floating above the terrain" because of correlation issues, or virtual characters "passing through walls" because the models were not attributed correctly. Until recently, creating the virtual terrain in applications was purely a manual activity, with artists, modelers, and programmers spending significant time and money to create one-off terrain datasets that were rarely able to be repurposed in other rendering environments. Limitations in processing and machine learning (ML), and poor-quality source data compounded the problem for decades, stalling attempts to fundamentally change the way terrain is created for virtual applications.

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However, in the past five to seven years, the introduction of cloud computing, better and cheaper CPUs and GPUs, and new sources of high-resolution terrain data (unmanned systems, airborne and terrestrial LiDAR, small satellites, and commercial mapping resources such as Bing or Google Maps) have provided new procedures for terrain generation.

The opportunity has arisen to reduce the time and cost for creating digital terrain by automating what were previously manual efforts. Automated functions include procedurally generated textures and polygons, the correlation and linking of datasets, and adding application-specific attributions to models that allow the simulation to reason with colliders, navigation meshes, and other entities. Adding semantic labels and metadata to the underlying data is critical so the engine can differentiate how the data is to be used at runtime (e.g., whether something will drive on it, shoot through it, move through it, hide behind it, etc.). Leveraging these advancements and combining them with automation routines has allowed the M&S community to exponentially grow its capabilities and output.

Expanding the Use of Reality Modeling Data

The field of geospatial intelligence (GEOINT) has rapidly evolved from paper maps with acetate overlays, to the digital 2D maps of the 1990s and 2000s, to the 3D/4D representations we see today. This data continues to grow in abundance and requires a new breed of cross-disciplinary collaboration and research to ensure its utility is maximized. Identifying and developing ways for users to exploit and better understand the 3D world is becoming increasingly relevant. The M&S community, through virtual and augmented reality (VR/AR), continues to dominate the generation and representation of realistic 3D mesh data; however, the integration and utilization of such data within the operational community has been very slow. Traditionally, M&S practitioners had no need for coordinate geometry, as typical VR/AR applications are self-contained or single-scene environments,

and did not need to sync with a real-world place in space, thereby limiting their utility in fusing with other spatially-aware operational datasets and GEOINT.

Furthering on the gains made in automation and increased productivity of M&S 3D datasets, the ICT team was asked to investigate the possibility and feasibility of "operationalizing" the M&S 3D datasets to support not only STE but the operational and geospatial needs of the warfighter.

Once the 3D data has been geospatially enabled, it becomes so much more than just simulation data; it becomes usable GEOINT. This data can then be leveraged in deployed environments by ground commanders, military planners, engineers, and practitioners for mission planning and rehearsal, terrain generation, route mapping and clearance, base layout and design, infrastructure planning, IED-modeling and post-blast assessment, cover/concealment, and more. For post-attack recovery efforts, practitioners can quickly send UAS to capture existing conditions, then model the damage and map unexploded ordinance to assess the situation and develop a recovery plan—while minimizing exposure to deployed troops. Operational units such as infantry and special operators can produce models to map the battlespace and to enhance defensive preparation efforts or model assault objectives.

It was in that vein that ICT reached out to both GeoAcuity and SSI for their geospatial acumen and DoD and IC support experience. This collaborative team yielded quick and beneficial results. The team was rapidly able to leverage the embedded geo-coordinates native to OWT's source imagery data, and with a few manipulations to photogrammetric processing routines, was able to output spatially aware 3D datasets that were geo-referenced and aligned to the correct place in space. These datasets were now operational across all spatially aware software utilized by both the operational and GEOINT Communities (ArcGIS, ArcPro, SOCET GXP, Google Earth, etc.). The team also identified that there were ancillary 2D datasets produced during the

3D generation process (high-resolution orthographic imagery, digital surface models, point clouds, etc.) that were of no use to the M&S community and were not being utilized. These abandoned/unused datasets are of tremendous value to operational and GEOINT communities, so the existing workflow was once again modified to be geospatially enabled and to provide these valuable datasets along with the 3D products. In addition, the team was able to discern the best data formats across both 2D and 3D to benefit the largest number of end users and make these high-resolution and valuable datasets as interoperable as possible.

Operationalizing Reality Modeling Data: The Current State of Development

Following on from the team's initial success in operationalizing and expanding the data offerings, they began working with operational units and the software packages they used to get feedback and do initial acceptance testing. Working closely with the Army Geospatial Center (AGC), the high-resolution, geo-rectified 2D datasets were successfully integrated into both the Army's Command Post Computing Environment (CPCE), which provides a software infrastructure framework and common interface for both data and services, and Joint Capabilities Release (JCR), the Army's next-generation friendly force tracking system currently fielding to Afghanistan. This upgrade builds on the situational awareness tool Force XXI Battle Command Brigade and Below/Blue Force Tracking (FBCB2/BFT), which is integrated on more than 120,000 platforms and fielded to every brigade combat team in the Army.

3D datasets were provided to Army intelligence directorates at the National Training Center, where they were able to view, interact, and perform analysis on the terrain utilizing Esri software. The team also worked with U.S. Special Operations Command partners to integrate both the enhanced 2D and 3D datasets into the Android Tactical Assault Kit (ATAK), a handheld device soldiers utilize for real-time, battlefield

situational awareness. This user testing and feedback, specifically from the ATAK user community, highlighted some deficiencies in the newly geospatially enabled datasets. End users were noticing significant elevation offset errors in the vertical (z value) representation of the data. It was determined that the commercial grade GPS units on the UAS were recording large spatial accuracy errors, especially in the vertical. Subsequent testing showed on average that there was an up to 2-meter horizontal error and up to 60-meter vertical error in the spatial accuracy of the datasets. While this level of spatial accuracy method is sufficient for some visualizations, situational awareness, modeling, and simulation applications (e.g., single-scene viewing), it is not sufficient for analytics or operational use due to the high error margins.

The team sought to rectify this issue through the utilization of a professional grade global navigation satellite systems (GNSS) base station and a real-time kinematic (RTK) compatible UAS. RTK positioning is a satellite navigation technique used to enhance the precision of position data derived from GNSS, such as GPS, GLONASS, Galileo, and BeiDou. It uses measurements of the phase of the signal's carrier wave in addition to the information content of the signal and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimeter-level accuracy.[1] This had a tremendous effect, improving the spatial accuracy of OWT's 3D terrain models down to centimeter (~5-cm) level accuracy in both the horizontal and vertical.

Operationalizing Reality Modeling Data: Possibilities for the Future

This research need stretches across the workflow from collection to application. Early efforts have led to many outcomes, including the purchase of Tactical Decision Kits (TDK) for the U.S. Marine Corps that allow small units to organically manage their own geospatial holdings. Unit operators now regularly collect image data and provide it to others in the force as well as to researchers for additional classification and segmentation experiments.

Future Advancements for OWT include provisioning the data for use not just by training and simulation systems, but for operations and other related functions—intelligence, logistics, planning, etc. The OWT program seeks to continue to migrate its collection and data-creation methodology so that the capability is organic and can empower the creation and control of geospatial data at the unit level as much as is possible.

An increase in direct ties to the broader geospatial enterprise such as AGC and the National Geospatial-Intelligence Agency (NGA) are critical, especially as more and more 3D terrain is created by units themselves. AGC and NGA serve as content managers and validation authorities for geospatial data, so ensuring a coordinated effort between them and OWT is a paramount focus moving forward.

Additionally, as AI improves both in capability and potential, OWT will develop and leverage various ML techniques that continue to improve classification and segmentation for the attribution of 3D datasets.

Finally, edge computing will serve as the glue for the vast array of content being produced and managed across the community. Existing network infrastructures are likely inadequate for sending/receiving gigabytes of data, so ensuring producers and consumers of geospatial data have the necessary computing locally that can be synchronized across the enterprise will be key. Ultimately, researchers hope to revolutionize the way the two communities collect, process, and serve 3D geospatial data with long-term goals being to obviate the need for human intervention, and to use automation to more quickly and cost-effectively deliver terrain data to the point of need.

Realizing a Live Intelligence Preparation of the Operational Environment

By Ben Conklin, Esri; Brigham Bechtel, MarkLogic; and Mathieu Goebel, Earthcube

Intelligence Preparation of the Operational Environment (IPOE) is a mandatory step toward the understanding of an area of interest and the planning of a relevant course of action (COA) to support the warfighter. The production of IPOE encompasses political, military, economic, social, information, and infrastructure (PMESII) identification, and through this, the ability to detect critical key nodes and vulnerabilities.

PMESII products describe the overlapping of systems and sub-systems independent from geographical scale—from city to province, and even conflict level. Thus, a holistic methodology can be used to derive a systemic analysis of those PMESII components. This systemic approach could be used to organize large-scale research, collection, and structured analysis to:

• Identify critical objects constituting the PMESII of any given operational environment.

• Define how those critical objects form interrelated entities.

• Produce a shared reference situation.

• Estimate the potential impact of any course of action.

Recent developments in technology enable automated monitoring of the PMESII elements and make it possible to process the exponential quantity of data available at scale. An AI-based approach to automation allows commanders to

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1. Lambert Wanninger. "Introduction to Network RTK." www.wasoft.de. IAG Working Group 4.5.1. Retrieved February 14, 2018.

take advantage of the growth in data sources—sensors, collection platforms, imagery, signals, and open source—and enables a dynamic intelligence product to present a more accurate view of the target environment at any moment in time.

Automated monitoring can trigger the spatial and temporal exploitation of data and the ability to swiftly assess and explore emerging issues in the operational environment, which impact the mission of the warfighter. An automated, dynamic IPOE helps modern militaries respond to today's fast and agile adversaries. IPOE must become a living product, evolving at the same pace as data collected to support the warfighter.

This article describes how such a novel and holistic approach would support the warfighter and offer adaptive and always up-to-date COA planning.

Importance of Big Data in the Foundation of IPOE/PMESII

The amount of data available to a modern commander could enable an unprecedented, comprehensive view of the operations environment on a massive scale with an up-to-the-minute picture of the battlespace. Information assembled and integrated at speed enables a new systemic and dynamic IPOE that incorporates all available PMESII data. Societal infrastructure, even in third world countries, now contains terabytes of publicly available information from digital records, sensors, and social media in near real time. Meanwhile, command intelligence professionals are challenged to integrate open-source intelligence streams, tactical reporting, and traditional reporting from HUMINT, SIGINT, and MASINT as quickly as possible. The growing volume and variety of data is stressing current intelligence analysis during the planning phases. This increases the fog of war during operations solely due to problems handling the massive volumes of various data types and structures.

It is no longer necessary for IPOE to end after the analysis of data collected during the planning phase, because with current AI and data processes we can push for a dynamic IPOE into the execution phase. In the past, the IPOE was drawn from analytic conclusions based on data collected before and during planning. Then, operational decisions were made, and the plan executed with little chance to update the data prior to launch or during an operation, but this is not necessary. The ability to have up-to-the-instant data for IPOE would reduce uncertainty and the fog of war, even during the execution of joint operations.

Up-to-the-minute collection of volumes of PMESII in a world of systems for even small areas is, however, quickly overwhelming current processes. Take, for example, a hostage-rescue scenario in a non-permissive environment against a terrorist force operating outside government control. The image below highlights some of the data points that must be assembled on a single building to run the operation.
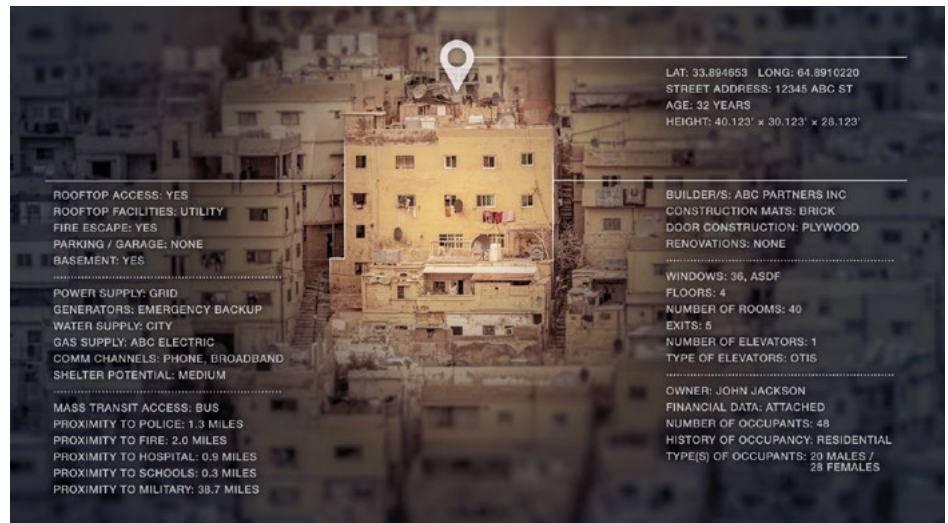

Figure 1. Example of complex information associated with one entity in IPOE.

For these complexes, sets of information requirements, with static and dynamic data that might be learned through traditional means, are often managed as structured foundation intelligence datasets. What is new and necessary in IPOE are to capture and model the dynamic human activities gleaned from various sources of information during planning and in real time. This operational data includes massive amounts of structured and unstructured data.

Commanders and policymakers are demanding a level of detail represented in the aforementioned graphics to make informed decisions, while our data systems attempt to integrate ever-increasing volumes and types of data for analysis. As the operation against a point target with limited objectives described, the volume of data available from just hours of video surveillance by a drone could be measured in terabytes—depending on the resolution of the camera, whether sound was included, and the type of camera file system used.

According to a Digital Rebellion video calculator, one hour of NTSC uncompressed, 10-bit video at a 59.94 frame rate and 720x480 resolution would result in 263.71 GB of data.

A critical element of all the data sources and streams will also be the collection of the metadata from these files to ensure the integrity and quality of the reporting that gets included and analyzed in our IPOE. It would also require constant human monitoring to feed into the PMESII available.

Integrating other data streams into the analysis (i.e., media, call data, imagery) grows the demand on our human-machine team with volume and both structured and unstructured data in a manner that could mean the loss of key indicators simply because of the volume and time required to process the information.

This increasing variety of data also increases exponentially in volume for actions across larger geographic areas when more PMESII information is needed

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to describe the theater of operations to a larger audience of friendly and/or allied forces, commanders, and policymakers. The expanded volume includes more data streams, sensors, and reporting from other sources. A data management environment capable of dealing with this complexity would help joint force commanders manage big data for IPOE.

Leveraging AI Inside IPOE

Most of the growing volume of data needs to be processed, conditioned, and analyzed to be leveraged in IPOE. This is when artificial intelligence (AI) comes into play. Facing the amount of data usable to populate the PMESII, no analyst is able to manually keep track of how all sources and relevant data evolve and change. A potential consequence of this is that a PMESII can quickly become outdated and thus endanger the IPOE and the ability to plan the most efficient course of action.

AI can support this process. Analyzing the elements of PMESII means to identify several entities for each dimension. Each of those entities can be identified and monitored through different sources of information. For instance, a power plant can be monitored thanks to imagery, open-source, and classified information sources. Likewise, the power grid in which this power plant is integrated and the human geography it exists within helps the analyst to understand how the population depend on this plant. Each time an analyst identified a source of information that provides updates on a regular basis, the analysis of those updates could potentially be automatized thanks to AI.

That being said, the first step to achieve this level of automation is actually to specify what are the key components of the operational environment you seek to monitor and how those can be broken down into systems and sub-systems and identify the interconnecting nodes between those. This is why AI and tradecraft always need to be intimately coordinated. The analyst helps to direct the AI, and the AI helps to reduce the burden on monitoring or updating datasets.

Once this is done, you can thus define your data model and the sources you need

to monitor. If one looks at international standards on this data model—for instance, the features listed in STANAG 2592—it is clear that the AI technology available today won't be able to process and monitor all those. Nonetheless, a significant number—one could say the critical ones—could be achieved. Below are few examples of data sources that could be monitored thanks to AI.
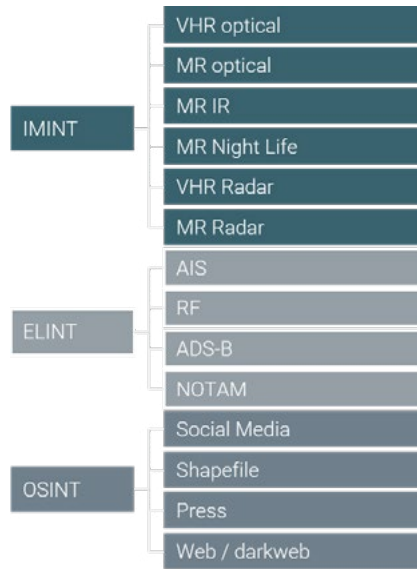

Figure 2. Examples of data sources used for an AI-enabled IPOE.

From a technological perspective, depending on the data source to be monitored, different AI technologies could be leveraged on natural language processing for text-based data, automated speech recognition for audio data, computer vision for imagery data, and overall machine learning/deep learning techniques when relevant. Once an AI agent was operational for each of those data sources, automated

processing could be then generated. Each time a source provides new data, these can then be processed thanks to the AI agent and its outputs aggregated into a georeferenced database. In other words, AI will be able to permanently interrogate databases in order to feed intelligence plans and consolidate information.

Over time, this recurring analysis allows us to derive a multilayered activity dashboard for each output from this source. This will allow the analyst to quickly and efficiently visualize patterns of life for each of the PMESII dimensions, how those vary from usual behaviors, and their level of influence on the overall analysis.

The IPOE, which was in the initial phases of the intelligence cycle, then becomes a living analysis with both geographical and pyramidal classifications. The analysis, in return, becomes easier and more time-saving. Figure 3 illustrates a possible dashboard made possible by such a concept.

Thus, AI and databases combined will give the information and decision-making operator a more complete, multilayered, and consolidated view. Supported by AI, the intelligence cycle will be denser and faster. Therefore, the strategic level may develop more comprehensive studies describing systems and anticipating their changes. Having identified the centers of gravity of the system, the strategic level can then offer to the political decision-maker a more complete analysis of the system and a set of actions to be taken, each affecting one or more centers of gravity.
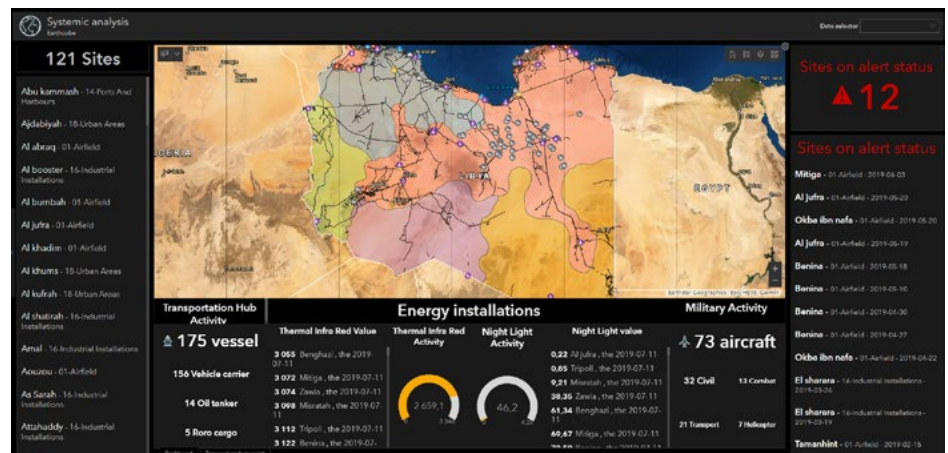

Figure 3. Example of an interface enabling live IPOE.

IPOE as a Dynamic Process

With the integration of big data and AI, the information feeds into IPOE are all dynamic. To take advantage of these advances, the IPOE process itself needs to evolve. In current doctrine, IPOE is described as a dynamic process, but we still see IPOE as a linear process that has four major steps:

1. Define the battlespace.
2. Describe the operational environment.
3. Evaluate the threat/adversary.
4. Determine course of action.

Each of these steps is integrated into the military decision-making process to inform operational planning. This sequential flow helps to create focused information products like the modified combined obstacles overlay, situation template, and decision support templates. Key information like Named Areas of Interest (NAIs) and High-Value Target (HVT) lists are used during the execution of the operation to confirm courses of action and contribute to running estimates.

Rethinking IPOE as a Continuous Cycle

The reality of intelligence support to decision-making is that the intelligence picture is often incomplete and uncertain, and it takes time and resources to reduce the uncertainty. To support an agile decision-making process, it is more useful to think of the IPOE process as a cycle (Figure 4). Each phase in the cycle has information products that inform the next phase in the cycle and can also be used as decision-making inputs.
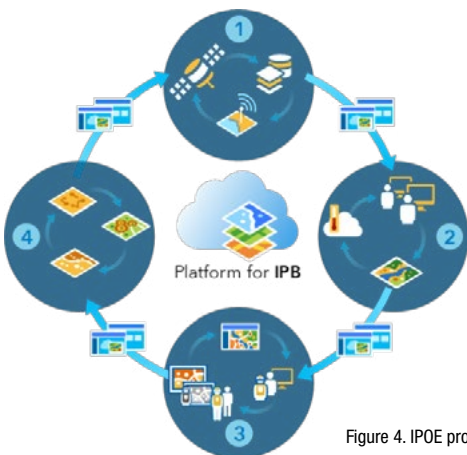

Figure 4. IPOE process and sub-process

This larger cycle is a series of four smaller cycles, which should each be running continuously. The work required to improve knowledge in each phase can be divided into teams, and each team can be focused on their step in the cycle. A short example helps to illustrate this concept. If a joint task force is assigned a mission in a new area of operations, the division of labor could be defined as follows:

A Battlespace Definition Team

Initial Task: This team starts the process by obtaining the authoritative foundational intelligence for the area of interest. This would include information like standard maps, current imagers, order of battle information, human terrain data, historical climate and weather data, and known threats. This information would be shared with the other teams. Significant characteristics or actives in the area that might impact operations are identified during this phase.

Refinement: The foundation team would leverage in-theater, national assets and open-source intelligence to improve the foundational sources based on the needs of the mission. This refinement is man-hour intensive and usually requires specialists in data management.

An Operational Environment Team

Initial Task: This team would start with the foundational intelligence and create analytic models based on mission parameters to create derived products depicting the potential impact the environment will have on operations. These products include items like cross-country mobility, obstacles, mobility corridors, and avenues of approach.

Refinement: As foundational intelligence, knowledge of mission parameters and knowledge of adversary capabilities

improve, analytic models would be refined and re-executed to produce up-to-date information products. Many of these models can run in an automated fashion using AI or statistical modeling but would need analysts to refine and shape them based on evolving parameters. This refinement is not as man-hour intensive, but does require trained analysts and data scientists to execute.

A Threat Evaluation Team

Initial Task: Identify threat force capabilities and the tactics, techniques, and procedures they employ. This task is completed using historical reporting and knowledge of the enemy and must be updated based on the mission parameters and conditions in the environment. Initial identification of high-value targets can occur based on the current picture and known mission objectives. This information is translated into dynamic graphic overlays and shared in real time.

Refinement: In today's threat environment, the threat force capabilities and threats to personnel (TTPs) need to be constantly reassessed based on new information and changing conditions. This information is refined based on new reporting and assessments, and should be updated continuously to support the planning process. These threats might be regular, irregular, or hybrid. The evolving nature of the threat requires a constantly evolving threat picture.

A Threat Course of Action (COA) Team

Initial Task: The development of threat courses of action requires understanding from all of the other key phases. The initial task will be to develop the threat COAs based on known information gathered in the initial phases. The output of this process would be the situation template and threat COA statement. Additionally, the event template can be built and named areas of interest identified. All of these graphics would be shared as live overlays.

Refinement: As the underlying knowledge of the operational variables is improved, the likely COAs need to be reassessed with updates to all of the key information products. By maintaining live

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connections to all of the information and relevant analytic models, this process can be streamlined for the analysts who are making the assessments.

A Digital Platform for IPOE

To support this workflow, the process for IPOE needs to be digitally transformed as well. Current IPOE workflows, while digital, still result in static products without any connection back to the data used to create the product. A digital approach for IPOE would shift the approach by providing two key outputs:

1. Dynamic and interactive information products.

2. Application-ready web services.

These two outputs would support decision-makers and analysts through dynamic, always up-to-date products. The sharing of dynamic and interactive information products would allow decision-makers to drill down on the products. They would be able to have up-to-date information at their fingertips when planning. The application-ready web services would provide access to the raw data for machines and humans to use in their own workflows and processes. This is critical because the ability to automate and streamline this process requires machine-readable data. The technology to realize this exists today, but the concept of employment needs to change to receive the decision advantage possible.

Conclusion

The technology and data to realize a live IPOE exists today. As more data is created, there will be an imperative to leverage this technology to maintain decision advantage against adversaries. The Intelligence Community will need a data environment capable of dealing with the volume of big data, both structured and unstructured. AI will need to be employed to support analysts actively monitoring and integrating data. Finally, this technology needs to be employed to support a dynamic process within the intelligence sections conducting IPOE. This will help commanders deal with the increasingly complex threats we face today. ⮐

⮕ GEOINT in NATO

By Dr. Todd Bacastow, Penn State; Dan Steiner, Orion Mapping; Stephen Handwerk; Dr. Gregory Thomas; and the Penn State Comparative GEOINT Seminar [1]

Research for this article was completed as part of Penn State's Comparative GEOINT educational series during the summer of 2019. The course included scholars from Penn State University and NOVA Information Management School (NOVA IMS), the School of Statistics and Information Management of Universidade NOVA de Lisboa.

This article is an examination of geospatial intelligence (GEOINT) in selected NATO countries and NATO itself. The acronym GEOINT is used throughout this paper as an abbreviation for "geospatial intelligence" and is not intended to connote a particular national definition, business process, or tradecraft. The research is multifaceted because of the two distinct parts examined. The first is a study and summary of GEOINT in the individual NATO countries of Belgium, Canada, Denmark, France, Germany, Norway, Poland, Portugal, Romania, Turkey, the United Kingdom, and the United States. The second examines GEOINT in NATO as an organization. Each NATO country researched has some capability to produce GEOINT-like products, but the GEOINT that NATO produces is largely a product of the NATO

Intelligence Fusion Centre (NIFC). The key takeaway here was that the production of GEOINT in a NATO member country is not necessarily the same as GEOINT in NATO. "National" and "NATO" GEOINT are fundamentally different phenomena. In fact, probably only a few NATO nations have GEOINT tradecraft that resembles that of the NIFC. Our research found good reason for this; a country's GEOINT tradecraft belongs to the nation's history, culture, and available resources. NATO GEOINT tradecraft belongs to NATO's history, diplomacy, and the U.S. support of the NIFC. We believe an understanding of both the individual countries and NATO are essential if one is to fully understand GEOINT in NATO.

NATO

The North Atlantic Treaty Organization (NATO)/Organisation du traité de l'Atlantique nord (OTAN) is a military alliance that has two official languages, English and French, as defined in the Articles of the North Atlantic Treaty. NATO/OTAN was founded in 1949 and today is a group of 29 countries from Europe and North America organized to

mutually protect its members. By explicit policy, a "NATO decision" is a collective decision and the expression of the shared will of all 29 member countries since all decisions are made by consensus. This "NATO decision" is not reflective of GEOINT produced by the NIFC.

The task of researching NATO was unexpectedly challenging. Despite the right-to-information laws of many NATO member nations, their laws do not supersede long-established and highly restrictive NATO Security of Information (SOI) requirements that the participant countries must meet for membership.[2] There is also the tendency in NATO to defer to the most restrictive SOI requirement. NATO's web of intergovernmental agreements further restricts even basic information.

GEOINT in the NATO Member Countries

Communicating and researching GEOINT concepts is easier for English-speaking countries because the predominant conferences (USGIF GEOINT Symposium and Defence Geospatial Intelligence)

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and literature are conducted in and published in English-language journals, magazines, conference proceedings, and books. However, many NATO member countries are non-English speaking, and the literature that originates within the country is not published, and, where it is published, the terminology is not consistent from a linguistic point of view. Since language and culture are intertwined, one cannot understand GEOINT in a culture and tradecraft without accessing its language. For example, the specific search terms used in researching a nation's GEOINT culture were a problem. Incorrectly, our researchers often assumed they would find information using the search term "GEOINT." Such searches were unproductive for many NATO countries, such as Turkey. To solve this, the researchers explored parallel topics such as mapping, imagery, and military geography and often found a wealth of information. But this gave rise to another question: "Now that we know what's happening, how do we determine if the country does GEOINT?"

Answering this question is a particular challenge when a nation does not explicitly use the term "geospatial intelligence." In the U.S., geospatial intelligence is defined by law, but in some countries, such as France, there is no specific term.[3] Addressing this problem, our research used a "three-way test" to determine if a nation developed GEOINT as an intelligence product.[4] The three-way test asks the following questions:

1. Does the result pertain to events that occur in time and space in relation to the Earth?

2. Does the result inform a decision-maker of human actions, objectives, or capabilities?

3. Does the result provide an advantage over a competitor or adversary that might withhold or offer deceptive information?

For the purposes of this study, if the answer to all three questions is "yes," then the country, agency, or product can be

said to be using, producing, or containing GEOINT. As stated in the introduction, each of the NATO member counties researched had some organic capability to produce GEOINT-like products.

Each of the NATO member countries listed was examined with regard to their community, business process, and work. While they all produced GEOINT, no two countries approached GEOINT exactly the same way. The countries were remarkably similar in GEOINT missions, supporting military/national defense, public safety/law enforcement, disaster response, peacekeeping, and, occasionally, less common missions like cyber geography and meteorology. All of the countries had a history of geographic studies and mapping with the strongest legacy of GEOINT-like practices in the U.K., Germany, France, Belgium, Netherlands, Luxembourg, and Portugal.

GEOINT practices in the individual NATO member nations have evolved from centuries of interrelated geographic thought and often confrontational histories. In recent years, the influence of the U.S. is evident in the technology, systems, and tradecraft. Clear collaboration occurs within the boundaries of established bilateral and multipartite agreements. The commoditization of GEOINT tradecraft and technology, such as high-resolution commercial satellite imagery, has created much more of an environment of parity among the NATO countries. Yet, research found there remains a diversity of technology and level of program development within NATO members.

A Critical View of Our Findings

In our goal to identify the process, methods, and products of GEOINT for selected member countries and NATO, three archetypical national structures emerged:

- **Project:** An example is France's Centre de Renseignement Géospatial Interarmées (CRGI), where GEOINT is developed in service centers that are oriented around project-based work.

- **Distributed:** An example is Germany's Federal Intelligence Service (BND) working with the Strategic Surveillance Command (KSA). Work is characterized by horizontal information and data flows created to take advantage of competencies across organizations.

- **Federated:** An example is the U.S. National Geospatial-Intelligence Agency (NGA), where there is unity of authority for the production of GEOINT.

These three structures can be more generally expressed as enterprise and ad hoc GEOINT organizations. An enterprise organization, as illustrated by the distributed and federated structures, is subdivided into various units, which are grouped together specifically to produce GEOINT products. The ad hoc organization, as shown by the project structure, organizes for a specific problem and is often not intended as a permanent grouping of dedicated units to produce GEOINT products. These structures may bear little relationship to the quality of the GEOINT produced. We also suspect there is an undescribed "X factor" that seems to make some ad hoc organizations exceptionally good.

Some countries (e.g., the U.S. and U.K.) had strong affiliations with industry. Here, contractors worked alongside government employees and across the intelligence enterprise. This included consultancies, integrators, and software developers. Affiliations with academia are more limited, and the U.S. seems to have led in promoting a relationship with academia. Many countries have international bilateral and multipartite agreements (e.g., FVEY, Multinational Geospatial Co-production Program, European Union Satellite Centre).

Recent history and intelligence oversight were linked. In several countries, intelligence services that exist today were only created after the fall of recent dictatorships. While these nations have moved toward intelligence practices similar to the longer established and democratic NATO member nations, there

3. Frédéric Hernoust, Thierry Rousselin, David Perlbarg, Nicolas Saporiti, Jean-Philippe Morisseau, and Jean-Daniel Testé. "GEOINT on the March: A French Perspective." *2018 State and Future of GEOINT Report*, 5-9. https://usgif.org/system/uploads/5489/original/2018_SaFoG_PDF_Final.pdf?1518125527
4. Todd S. Bacastow. Comparative GEOINT Seminar. Penn State University. 2019.

is still a particular cultural resentment and distrust in the former one-party states toward intelligence due to the history of oppression.[1]

It was difficult to identify the business process of particular countries beyond that of the U.S. The most commonly referred to high-level business model was the intelligence cycle. Often cited in the U.S. was the TPED (Task, Process, Exploit, Disseminate) process, but the TPPU (Task, Process, Post, Use) is also found. In all countries, the overall business process was a "system of systems" including people, systems, and subprocesses that provided context and meaning to the raw data. There was an identified trend toward technology to process the massive amounts of available geospatial data, creating a demand for workers with technical and analytical skills. Some nations, such as the U.S., fill the need with public-private partnerships between the government's GEOINT Community and academia. Other countries, such as the U.K., prepare workers both "in-house" and in public academic institutions.

Using the definition of tradecraft as a set of methods, techniques, and skills that form the science and art of producing GEOINT, the nature of tradecraft in the NATO countries we examined was difficult to identify. While it can be said that each country was unique, we also observed that emerging tradecraft is influenced by NGA in the U.S. There is also evidence of a general movement toward viewing GEOINT in the character of all-source fusion. In the acquisition of technology, there was a movement away from government off-the-shelf (GOTS) and NATO off-the-shelf (NOTS) toward commercial off-the-shelf (COTS) software. Where present, the expansion of national space and UAV programs are points of pride and provide a source of independence and economic opportunity (e.g., Canadian RADARSAT

Constellation, Belgian Helios, German SAR-Lupe, Portuguese PoSAT, and Turkish Türksat6A).

This experience suggests replicating our examination of NATO GEOINT using an evaluation model based on a systems science approach. The *systematiska utvärderingar* (SUV) (systematic evaluations) model is a framework based on systems thinking and examines the span of activity. The SUV model partitions an evaluation into seven categories and three levels. The seven categories, selected based on systems science and systems thinking, are goal-seeking, hierarchy and relations, differentiation and entropy, inputs, transformation process, outputs, and regulation. The model also provides an evaluation at the three levels of organization, technologic, and individual.[2]

GEOINT in NATO

In 2008, the U.S. Central Intelligence Agency (CIA) released an unclassified version of a 1984 article titled, "Design for Dysfunction, NATO Intelligence: A Contradiction in Terms," in *Studies in Intelligence*. As the title suggests, it described NATO Intelligence as dysfunctional, highlighting the lack of intelligence integration in NATO.[3] Since then, NATO adapted to the challenges with the creation of the NATO Intelligence Fusion Center (NIFC) at RAF Molesworth, U.K. The NIFC allows NATO nations to jointly develop, fuse, and share information in support of NATO out-of-area operations.

NATO's Military Committee chartered the NIFC in October 2006 as a military-led, U.S.-sponsored "NATO Military Body with International Military Headquarters Status" to improve operational intelligence cooperation and support the International Security Assistance Force in Afghanistan. The U.S., as a framework nation and the provider of classified and

open-source information, integrated non-U.S. personnel into the NIFC and incorporated intelligence input from member states to produce non-agreed all-source intelligence.[4] The goal was expressed by Gen. James L. Jones when he opened the NIFC as, "to share, not to protect" information.[5] Significantly, if NATO did not support the NIFC's creation, the U.S. was prepared to establish a center as a U.S. initiative.

Then, as it is today, not all NATO nations are integrated among the NIFC elements. The U.S. holds leadership. The various nation elements are dispersed with no compartmentalization in the NIFC building. However, there are "National Rooms" outside the NIFC building for secure communication with their respective national assets, supporting the necessity and value of reachback while formalizing the process of intelligence sharing. By charter, the NIFC does not produce "agreed intelligence." This is to say that an "NIFC analysis" is not necessarily the shared expression of all who contribute to the NIFC's work since the analysis does not represent total agreement. However, NIFC's products are shared with all NATO members as an incentive for NIFC personnel to cooperate and member countries to provide professional staff.

Joseph Gordon, in the *Encyclopedia of U.S. Intelligence*, states that "perhaps the biggest volume of Request for Information (RFI) responses has been for various geospatial products, an excellent example of the NIFC's ability to harness U.S. intelligence support directly to NATO." Again, according to Gordon, the "U.S. [NGA] works closely with the NIFC supplying analysts and data to support the mission." NGA views the NIFC as an organization, "where analysts from NATO nations work together on critical GEOINT products, an excellent environment in which to teach each other and develop tradecraft."[6]

1. João David. Personal communications. 2019.
2. Paivi Jokela, Peter Karlsudd, and Martin Östlund. "Theory, Method and Tools for Evaluation Using a Systems-based Approach." *The Electronic Journal of Information Systems Evaluation*. 2008:11(3):197. http://www.ejise.com/issue/download.html?idArticle=732
3. Edward Atkeson. "From the Archives-1984: Design for Dysfunction—NATO Intelligence: A Contradiction in Terms." *Studies in Intelligence*. Volume 53, Number 1. (CIA: 2009). https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol53no1/ (accessed October 16, 2012), 1.
4. Jan Ballast. "Merging Pillars, Changing Cultures: NATO and the Future of Intelligence Cooperation Within the Alliance." *International Journal of Intelligence and CounterIntelligence*. 2018:31(4):720. https://doi.org/10.1080/08850607.2018.1488499
5. Bryan Mitchell. "NATO Intelligence Fusion Center opens in England." *Stars and Stripes*. 2006. https://www.stripes.com/news/nato-intelligence-fusion-center-opens-in-england-1.55546
6. Joseph Gordon. "NATO Intelligence Fusion Centre (NIFC)," in Gregory Moore, ed., Encyclopedia of U.S. Intelligence. New York: Taylor and Francis, 2014. Vol. 2, pp. 647–648.

Conclusion

To understand NATO GEOINT, it is essential to understand two distinct parts. One part is GEOINT conducted in NATO member countries. The second is GEOINT produced in NATO. In studying the NATO member countries of Belgium, Canada, Denmark, France, Germany, Poland, Romania, Norway, Portugal, Turkey, the U.K., and the U.S., we found that "national" and "NATO" GEOINT are fundamentally different phenomena. We found that a country's GEOINT tradecraft belongs to the nation's history, culture, and available resources. This is contrasted with NATO GEOINT tradecraft, which belongs to NATO's history, policies, and the U.S. support of the NIFC. The work illustrates how studies of GEOINT organizations have important value. Above and beyond this, the impact of a mixed group of international researchers was strategic and enlightening. One of the primary outcomes of the course was to break down the boundaries between academic institutions and reveal cultural insights among the international GEOINT community.

Recommendations

There are three primary recommendations that emerge from this work. First, educators need to promote the study of GEOINT organizations to better understand their behaviors, practices, and processes. Second, a mixed group of international learners and researchers should be encouraged. The international mix of students that participated in the course created relationships among academic institutions and developed shared cultural insights. Last, there is a need to improve the means of investigating GEOINT organizations and capabilities. A systems science approach might better capture the set of methods, techniques, and skills that form the tradecraft of producing GEOINT.

The Role of GEOINT in the Integration of Commercial, Small UAS into the National Airspace System

By Dr. Bradley M. Battista, Battlespace, Inc.; Gregory T. Foscue, Unmanned Systems Alaska, LLC; and Dr. Catherine F. Cahill, University of Alaska Fairbanks

Geospatial intelligence (GEOINT) is "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information."[7] Most people understand GEOINT to be the various forms of satellite imagery supporting a geographic information system (GIS) used to understand a variety of activities acting upon the Earth, and that's partly correct.

However, GEOINT comes from far more sources than from satellites alone. Moreover, GIS and GEOINT are not the same thing. GIS is to GEOINT what timber is to a house. Of the many uses for timber, supporting the framework for a house is but one. While some use GIS and GEOINT interchangeably, it is important to remember that GEOINT, like a house, is focused on the human more so than the Earth. A fun way to explore GEOINT is to apply the prefix "geo" to a human activity and review the concepts that come to mind (i.e., geo-political, geo-economic, geo-healthcare, geo-retail, geo-transportation, etc.). This "geo-cognitive" exercise will quickly replace the solid lines between geospatial disciplines with dashed lines, and this is a good method for beginning to understand GEOINT tradecraft. In this article, we explore how the GEOINT tradecraft is evolving within the aviation industry through the introduction of unmanned aerial systems (UAS) into the National Airspace System.

Types of GEOINT

There are two widely recognized arenas for GEOINT. First, the U.S. Intelligence Communities rely on GEOINT to support their national security mission objectives. Second, commercial industries are increasingly using GEOINT to both sharpen their competitive edge and to better know their customers. There are two commercial GEOINT subtypes: *active* and *passive*. Active GEOINT is intentionally created and distributed, while passive GEOINT is inadvertently or unknowingly created and distributed. We focus on commercial GEOINT in this review because it is the enigmatic source of unprecedented volumes of data. Commercial GEOINT is difficult to regulate as it comes from numerous sources having various accuracies, is potentially spoofed, and is most readily available to adversaries.

Commercial GEOINT is created by and for commercial, and often public, use. While it is true that commercially owned satellites contribute invaluable data streams to commercial GEOINT, it is also true that consumer products are contributing as much or more. The smartphone, for example, is the quintessential source of consumer-produced commercial GEOINT. We present smartphones, and mobile devices in general, as a metaphor for understanding unmanned aerial systems (UAS). In fact, there are cases where a smartphone served as the "brain" of a UAS.[8,9]

Mobile devices are capable of producing high-resolution geotagged images. They are also capable of producing geo-referenced social media, interacting with Internet of Things (IoT) automation services, and using artificial intelligence

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7. National Geospatial-Intelligence Agency. 2006. "NSG GEOINT Basic Doctrine Pub 1.0."

8. Mateo Borri. 2017. *RobotsEverywhere - Air*. https://robots-everywhere.com/re_site_wp/robots-everywhere/air/

9. David Steitz and Rachel Hoover. 2013. *NASA's Latest Space Technology Small Satellite Phones Home*. December 4, 2019. https://www.nasa.gov/press/2013/december/nasas-latest-space-technology-small-satellite-phones-home.

(AI). Mobile devices are so good at producing and interacting with geospatial content, they have earned a place in the tool kit of professional surveyors. Professional surveyors commonly use mobile devices to supply kinematic corrections from virtual reference stations, making mobile devices tools for improving positional information to subcentimeter accuracy. Another compelling play for mobile devices is how they can turn any consumer into a potential surveyor. In this context, a consumer may actively or passively contribute geo-technical data to a commercial entity.

This type of GEOINT transaction between a business and its consumers typically comes in the form of a consumer convenience. Consider a crowdsourced navigation application that allows individuals to share traffic conditions in real time. The consumer actively exchanges traffic data with other consumers while passively providing detailed knowledge of traffic patterns, consumer route history, and any associated metadata (photos, contacts, etc.) to the application provider. This example involves the transfer of both active and passive GEOINT.

Now consider how the crowdsourced navigation application above scales when consumers, or drivers/pilots, are replaced with AI, and the equipment they control becomes autonomous. This consideration reveals the necessity of traffic management for unmanned systems, and prepares us for understanding the challenges presented during the integration of UAS into the National Airspace System. How are location-enabled mobile devices different from UAS? Both are mobile, potentially interacting with humans, capable of gathering intelligence, making decisions from that intelligence, and disseminating that intelligence. And both have been shown to exhibit machine-to-machine backchanneling at times. This presents significant GEOINT concerns, as well as an added concern in the form of supply-chain security risk.

A GEOINT-UAS Knowledge Gap

Working with GEOINT involves tradecraft, and it is difficult to define GEOINT tradecraft beyond a dynamic interaction with GEOINT. The tradecraft is both multidisciplinary and cross-industry, resulting in competing ideas and applications across industry lines. The lexicon is evolving even within the Intelligence Community. So, it's not surprising that GEOINT sits on the periphery of the commercial UAS industry. Presently, the UAS industry is focused on safely operating in the National Airspace System with increased complexity and autonomy. New standards for pilot certification, airworthiness, and airspace authorization are emerging, quietly and diligently increasing the presence of GEOINT in the commercial UAS industry. Together, the emergence of GEOINT and UAS standards and protocols makes them difficult to discuss despite a growing codependence. To help clarify this codependence, let us first walk through the stages of UAS developments and point out the crucial stage where GEOINT becomes relevant.

sUAS Traffic Management

As you may know, the Federal Aviation Administration (FAA), NASA, and other federal and industry partners have been collaborating to develop a sister traffic management system to the FAA's manned Air Traffic Control. The sister system is designed to serve UAS weighing less than 55 pounds and operating below 400 feet. Specifically, these are small UAS (sUAS). sUAS operations are expected to produce a low-altitude (Class-G) air traffic density that requires a dedicated traffic management system, hence the imminent UAS Traffic Management (UTM) system.

UTM development was planned to include four technical capability levels (TCLs).[1] TCLs are not described with respect to GEOINT, and we put forth the notion here that the presence of GEOINT increases with each TCL as shown in Figure 1. Each TCL introduces improved operational capability in favor of autonomy, and the human pilot is incrementally replaced with AI. The resulting intelligence is aware of its environment through sensors and is intended to operate near people and eventually interact with them.

Technical Capabilities Level 1
TCL 1 was achieved at Integration Pilot Program (IPP) test sites by FAA-approved academic and industry partners in Fall 2015. Reserved airspace was mandatory, and the types of activities focused on demonstrating surveillance and reconnaissance for industrial monitoring. Agriculture, forestry, natural processes (e.g., wildfires), and infrastructure monitoring were all demonstrated in TCL 1. All TCL 1 operations were conducted within visual line of sight and
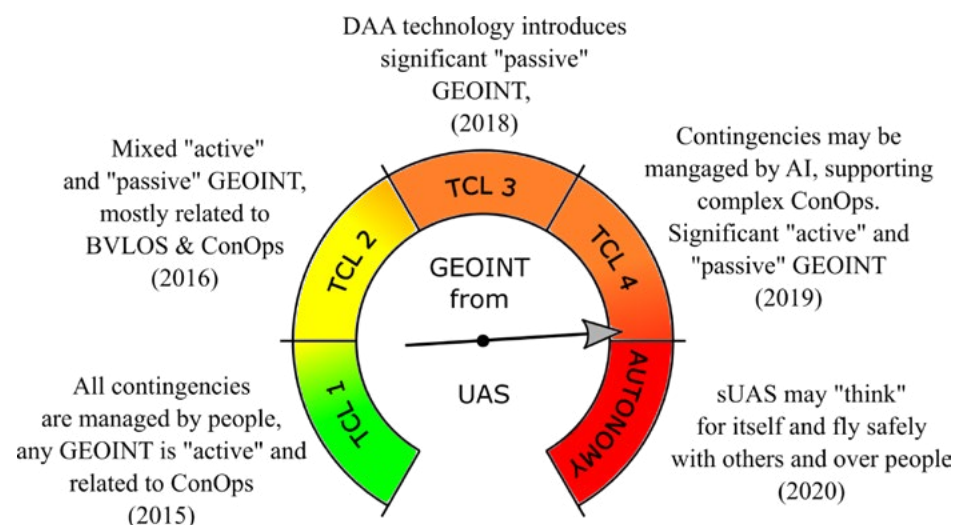

Figure 1. Codependence of UAS technical capabilities levels (TCL) and GEOINT. The presence of GEOINT increases as UAS become more autonomous.

1. NASA-FAA. 2018. "UTM ConOps v1.0." *UTM Concept of Operations Version 1.* https://utm.arc.nasa.gov/docs/2018-UTM-ConOps-v1.0.pdf

remotely piloted by a human pilot. All contingencies were handled by the pilot. Any GEOINT involved at TCL 1 resided with the pilot and was not essential to the sUAS operation.

Technical Capabilities Level 2

In just over a year, TCL 2 was achieved. Operations that demonstrated capabilities for flying beyond visual line of sight were introduced, as well as dynamic airspace reservation. This expanded the TCL 1 operations to include third-party tracking of an sUAS. TCL 1 and 2 were both conducted in sparsely populated areas. Some contingencies were handled by the sUAS with pilot supervision. Minimal GEOINT was present as sensors assisted crew with information in support of flying beyond visual line of sight.

Technical Capabilities Level 3

TCL 3 was achieved in 2018. The extra time required resulted from added complexity of capabilities. In contrast to TCL 1 and 2, TCL 3 allowed for ground observers to include sensors in addition to humans. Both responsive and nonresponsive sUAS tests were conducted to help determine how to manage sUAS that were "noncooperative." TCL 3 allowed for operations to be tested in moderately populated areas. Other tested capabilities included tracking and communication with other sUAS as well as managing cargo. Some contingencies were handled by the sUAS without pilot supervision. Developments in the hardware used for sensing and avoiding were coupled with AI, and this significantly elevated the presence and use of GEOINT through the use of detect-and-avoid (DAA) and sense-and-avoid (SAA) technology.

GEOINT, DAA, and SAA

TCL 3 introduced capabilities for DAA and SAA technology to an sUAS. It is important to note that DAA and SAA technologies are responsible for providing information to an onboard AI system that decides how to manage obstacles. It is also important to note how these technologies afford a greater range of capabilities to an sUAS than their implied purpose. Sensors that support DAA and SAA can include optical, acoustical, and image processing strategies. The combination of onboard sensors and intelligence allows an sUAS to manage UTM goals, as well as operate under conditions in which communications and positioning capabilities have been compromised, such as link loss or denied GPS. Therefore, an sUAS operating near airports, infrastructure, or other sensitive areas is gathering intelligence as part of its safety strategy, and this intelligence undoubtedly includes GEOINT. The acquisition of GEOINT using DAA and SAA technology is a security concern because the intended use for the data may change depending on the context in which it serves a given ConOps.

Technical Capabilities Level 4

TCL 4 advancement has been intensifying since early 2019. TCL 4 milestones include short, autonomous flights using radar-based ground observers and onboard tracking and avoidance systems.[2] The first demonstrated operation beyond visual line of sight without ground-based observers of any kind was completed.[3] Contingencies were handled by the sUAS. Urban operations, operations over people, and operations at night were also demonstrated. Safe operation beyond visual line of site without human oversight further increased the integration of GEOINT into UAS operations.

Both GEOINT subtypes (active and passive) are present in TCL 4. Furthermore, both active and passive GEOINT may be utilized in support of flight operations and/ or a ConOps. There are conditions where active and passive are interchangeable, based on context. For example, flying (without surveying) near a pipeline or nuclear power plant reveals structural information to the DAA system. Such intelligence is active GEOINT with respect to safe flight operations but may become passively associated with communication to air traffic control, ground control stations, and third-party service providers.

Beyond TCL 4: Autonomy

The capabilities demonstrated in TCL 4 mark a pivotal role in UTM development where a shift must be made from sUAS safety to sUAS security. The next phase of UTM requires sUAS data to flow through a developing UTM system. This means that intelligence generated onboard an sUAS will begin moving through UAS service suppliers in support of UTM goals, potentially carrying unrelated GEOINT in support of ConOps goals.

Moving Past the GEOINT-UAS Knowledge Gap

The presence of GEOINT in UAS operations grows with each milestone in the developing UTM system. Further, GEOINT is independently and inseparably tied to the safe operating procedures and the ConOps behind each mission. The rapid growth of the sUAS industry carries so much momentum that our GEOINT cards may sometimes be dealt face up. And just like with mobile devices, this may be tolerated for some applications while it is unacceptable for others.

The FAA's mission lies in regulating aviation within the National Airspace System, primarily through traffic management. The FAA will soon be presented with streams of GEOINT coming from UAS. How will the FAA, or any agency affected by GEOINT coming from unmanned systems, handle this? Unmanned systems are also found on land and in water. The answer is that these organizations likely are not equipped to handle these GEOINT streams. Instead, the data must effectively flow across a team of agencies, each one preparing the data stream for the other in such a way that security and safety remain optimum. Intelligence gateways, "GEOINT Gateways," need to be embedded within unmanned systems industries, and the National Geospatial-Intelligence Agency will require a panoptic view of these gateways. The data flowing to and through law enforcement will undoubtedly differ from the data flowing to and through Amazon, Google, UPS, and the like.

2. AUVSI. 2019. "University of Alaska Fairbanks Team Completes First FAA-Approved BVLOS Mission in the U.S." August 5. https://www.auvsi.org/industry-news/university-alaska-fairbanks-team-completes-first-faa-approved-bvlos-mission-us
3. Isabella Lee. 2019. "Iris Automation Detect-and-Avoid System Earns Second BVLOS Waiver and Trust of FAA." *UAV Coach*. August 22. https://uavcoach.com/iris-automation-bvlos/

GEOINT Gateways will be required to move information with improved bandwidth compared to that seen in HTTP-based communication. Edge computing, IoT messaging protocols, and decentralized architectures are all growing in tandem with the need for these GEOINT Gateways, and they will likely combine in the solution. This is less of a big data problem and more of a distributed "Big IoT" problem for unmanned-systems and intelligence industries to collaboratively solve. ↻

↻ Advancing GEOINT Through Clarity in the Employment Market

By Talbot Brooks, Delta State University; Dr. Christopher Anderson, GSX; Dr. Robert Austin, Austin Communications; Dr. David Alexander, U.S. Department of Homeland Security; and Dr. Camelia Kantor, USGIF

Finding high-quality candidates for positions in the greater geospatial intelligence (GEOINT) industry is an ongoing challenge for many employers because of high variability across the educational and training landscape, as well as the extraordinarily varied experiences brought by employees. Likewise, jobseekers have an equally difficult time discovering suitable positions because of the wide variety of titles used and a lack of clarity about the required level of competency needed in position descriptions. Both factors combine to stymie education, business, and government efforts to quantify and substantiate workforce needs and better prepare future candidates.

Anecdotal evidence indicates that confusion in the GEOINT employment marketplace has tangible consequences. Significant salary mismatches across seemingly similar positions, high turnover prompted by employer and employee dissatisfaction, and inconsistency across academic and training curricula are all symptomatic of dysfunction, which ultimately translates into what are widely reported as significant financial and productivity losses for both employer and employee. Peer-reviewed literature strongly supports the idea that improved selection processes, particularly those related to motivational fit, can improve both operations and profit.[1]

Refining the education and training pipeline such that it more closely aligns with position titles and job descriptions is an important first step in minimizing such losses. Three essential actions have begun to address this challenge:

1. Redefining the codification of occupations and academic programs.

2. Segmentation and professionalization of the workforce.

3. The creation of a body of knowledge focused on learning objectives rather than topics.

While these three initiatives represent substantial progress, they fall short due to a lack of comprehensive industry leadership and a clear vision of the future for GEOINT as an industry and an academic discipline. In article, these positive first steps are identified and potential solutions discussed.

Codification of Occupations and Academic Programs

President George W. Bush's administration identified geospatial technologies as a high job-growth area in 2001.[2] A substantial investment commitment was desired for the geospatial arena, but was quickly mired by a lack of definition around the terms related to all things "geospatial," and a debate over whether it constituted an industry. The Association of American Geographers, the Geospatial Information and Technology Association, and the U.S. Department of Labor's Employment and Training Administration (DOLETA) collaborated to form the Geospatial Industry Workforce Information System (GIWIS) in an effort to:

• Develop a constructive definition of the geospatial industry.

• Develop a web-accessible server of industry, job, and educational information called GIWIS.

• Create an industry image and outreach campaign.

• Develop a local pilot program for using GIWIS.

• Take steps to ensure the sustainability of GIWIS and the outreach program.

Numerous roundtable meetings of thought leaders solicited input about these topics from more than 200 representatives from across industry, academia, and government in an attempt to build consensus. The following definition was eventually reached and integrated into a web portal designed to meet the needs of industry, academia, and jobseekers:

"The geospatial industry acquires, integrates, manages, analyzes, maps, distributes, and uses geographic, temporal, and spatial information and knowledge. The industry includes basic and applied research, technology development, education, and applications to address the planning, decision-making, and operational needs of people and organizations of all types."[3]

The work performed in creating the definition and portal represented the first truly large-scope effort at understanding the emerging geospatial industry using a massive, consensus-driven process. At the same time, but independent from the civilian geospatial world, the idea of defense activities that used geospatial technologies and tools was maturing from a map/observe/report

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1. Matthew O'Connell and Mei-Chuan King. "The Cost of Employee Turnover." *Industrial Management*. 2007:49:1:14-19.
2. Geospatial World. "GITA Receives $700,000 Grant from U.S. Department of Labor." As reported on July 22, 2005. Retrieved on October 20, 2019 from https://www.geospatialworld.net/news/gita-receives-700000-grant-from-u-s-department-of-labor/.
3. GIWIS portal as was available through 2010 at http://www.giwis.org. A summary presentation, including screen shots, is available at https://www.fgdc.gov/ngac/meetings/december-2010/geospatial-industry-workforce-information-system.ppt.

perspective to contemporary GEOINT. The lack of connection between the burgeoning GEOINT and civilian geospatial communities was evident when comparing the above definition of the geospatial industry to the explanation of GEOINT offered by then National Geospatial-Intelligence Agency (NGA) Director James Clapper in 2005—the same time period in which GIWIS was ongoing:

"GEOINT encompasses all aspects of imagery … and geospatial information and services. … It includes, but is not limited to … the analysis of literal imagery; geospatial data; and information technically derived from the processing, exploitation, literal, and non-literal analysis of spectral, spatial, and temporal … fused products (that is, products created out of two or more data sources). … These types of data can be collected on stationary and moving targets by electro-optical …, [synthetic aperture radar (SAR)] …, related sensor programs …, and non-technical means (to include geospatial information acquired by personnel in the field)." [4]

Both the defense GEOINT and civilian geospatial technologies communities were working toward a similar fundamental understanding but were compartmentalized because there was little coordination or overlap in their respective efforts. This lack of connection would have far-reaching consequences because the resulting systems for educating jobseekers about the greater geospatial industry would flow from GIWIS and downstream. Subsequently, three systems would come into play:

1. The U.S. Department of Labor's Bureau of Labor Statistics (BLS) Standard Occupation Code (SOC) system, which is used for classifying federal agency employees into occupational categories.

2. The U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS) and its supporting Classification of Instructional Programs (CIP) coding system.

3. Department of Labor-sponsored workforce development systems at

the national level, such as O*NET, and related systems at the state level. These systems match SOC entries with CIP codes, allowing jobseekers to identify potential careers and match them with corresponding education and training programs.

At the start of the GIWIS project, BLS SOC entries in the geospatial realm only existed for "cartographer," "surveyor," and "photogrammetrist." Their corresponding CIP codes pertained largely to engineering, surveying, draftsman, and geography programs, with the latter lacking any sub-specializing code for geospatial technologies. The National Geospatial Advisory Committee, a federal advisory committee to the Federal Geographic Data Committee (FGDC), acted upon GIWIS recommendations to work closely with industry and BLS to expand the SOCs for geospatial jobs to include the following classifications:

- Geographic Information Systems Technicians (15-1199.05)
- Geospatial Information Scientists and Technologists (15-199.04)
- Cartographers and Photogrammetrists (17-1021.00)
- Mapping Technician (17-3031.02)
- Geodetic Surveyors (17-1022.01)
- Remote Sensing Scientists and Technologists (19-2099.01)
- Remote Sensing Technicians (19-4099.03)
- Surveying and Mapping Technicians (17.3031.00)
- Surveyors (17-1022.00)
- Geoscientists: Except Hydrologists and Geographers (19-2042.00)
- Geographers (19-3092.00)

The academic and training side of the equation (CIP codes) were much slower to respond, partly because geospatial technologies were largely considered tools to be used across academic disciplines, often ending up within the geographer's toolbox. Geospatial

technology education was largely relegated to the role of skills training via certificate, minor, and concentration level within four-year academic geography programs or offered as skills courses at the community college and industry training levels.

These perceptions have evolved over time toward a more contemporary notion of GEOINT, largely due to tremendous outreach efforts from NGA. The result within the CIP system is that GEOINT will move from 29.0203, Signal/Geospatial Intelligence in the "Military Technologies" family of disciplines to 43.0407 in the "Homeland Security, Law Enforcement, Firefighting, and Related Protective Services" family in the IPEDS 2020 update. While this update does not capture the true nature of GEOINT and geospatial technologies—an analytic, technology-centric lens for interpreting and understanding the geographic nature of phenomena and processes—it does begin to unite traditional civilian and military views of geospatial technologies toward each other.

The ramification is that links between workforce classification and education/ training preparation remains, at best, incomplete.

Segmentation and Professionalization

The Brooks Act of 1972 (Public Law 92-582) requires licensure for professionals engaged in federal projects requiring surveying, mapping, and engineering skills. Selection of firms for federal projects is thus based primarily upon qualifications and not bid price. Industry leaders and professional societies have long clashed over the definition of mapping.[5] This conflict has raised awareness about the need for workforce credentialing and spurred academia, professional societies, businesses, and governmental entities into disjointed action. The result of these efforts is a confused landscape for the uninitiated.

4. Barry Barlow. "The Future of GEOINT." *Trajectory Magazine.* 2017. U.S. Geospatial Intelligence Foundation. Retrieved from https://trajectorymagazine.com/the-future-of-geoint/ on October 20, 2019.
5. Management Association for Private Photogrammetic Surveyors v. United States. 492 F. Supp.2d 540 (E.D. Va. 2007).

Dr. Darryl Murdock, former Vice President of Professional Development at the United States Geospatial Intelligence Foundation (USGIF), parsed the GEOINT credentialing landscape as follows:[1]

- Certificates that mark the completion of a specified training or education course by any provider. The awarding of a certificate may be based upon simple attendance at an industry-sponsored training event or associated with successful completion of a rigorously graded academic course of study such as that associated with USGIF Collegiate Accreditation Program.

- Certification which assesses, usually through examination or similar evidentiary means, mastery of a body of knowledge or skills. Certifications may be independently accredited as a means of ensuring quality, as is the case of the USGIF-Certified GEOINT Professional and the NGA Geospatial Professional Certification programs. Or, they may be granted organizationally as is the case with the GISP certification from the GIS Certification Institute.

- Academic degrees denote competency-based mastery of a curriculum or body of knowledge related to a discipline or field of study. However, the link between degree competencies is not readily transparent and varies significantly among academic institutions. Independent professional accreditation of academic degree programs is a remediation for this variability and is exemplified by USGIF's accreditation of colleges and universities.

- Licensure whereby governmental authority is used to coordinate and regulate evidence-based processes required for practice. Surveying and engineering require licensure.

Thoughtful consideration about these position titles, workforce needs, and available education and training opportunities can be used to divide the GEOINT labor marketplace into two general categories: technician and professional.

Technicians use GEOINT methods and techniques to perform relatively routine tasks within an established set of protocols or boundary conditions. Some innovation and freedom of thought is allowed, even encouraged, but strictures, such as review of methods and/or data, are put in place. Technician positions are often highly specialized and may perform tasks of a high degree of complexity within a relatively narrow framework of conditions and are most often prepared through community college, entry-level military training, or industry-based training.

GEOINT professionals are those who create and/or use the technology to render judgments that affect quality/quantity of life and value of property. A profession generally consists of: a codified set of professional standards and practices; specialized education recognized by an authoritative body; establishment of a code of conduct/method for self-regulation that protects the public and general welfare; professional credentialing; and continuing education.

Conceptualization of position responsibilities with respect to technician and professional perspectives will help align position titles and descriptions with credentials. For example, a position requiring a candidate to digitize features from imagery using a particular software package may be best staffed by a candidate holding an industry-specific training certificate or an entry-level certification specific to GIS (USGIF's new entry-level Essentials certification) and who has perhaps completed an accredited certificate program or earned an associate's degree. Such a position should be titled "technician," and the aforementioned credentials included in the position description.

Likewise, a position requiring the development of a comprehensive GIS for emergency services may seek candidates with multiple industry software certificates, a journeyman or higher-level certification (USGIF CGP-G and CGP-D), and an accredited baccalaureate degree. This differentiation is not meant to imply

that one position is more important than another, or to create an artificial intellectual hierarchy within industry, but rather it establishes a means of linking credentials to positions.

A Recognized Body of Knowledge

A body of knowledge is a core requirement for refinement of CIP codes, the SOC system, and credentialing. Early efforts were established by the University Consortium for Geographic Information Science (UCGIS) in the late 2000s. Driven by academia and informed by industry, the resultant work, the GIS&T Body of Knowledge (BoK), segments "geospatial" into 10 conceptual categories. Each category is further divided into topics and sub-topics that are supported by associated learning objectives. It is comprehensive and well founded, but is largely an academic work—written by and for academics, does not extend deeply into the use of geospatial technology for exploiting information or co-requisite "soft" skills (i.e., communication and reporting), and is not segmented by knowledge level.

USGIF began working on its GEOINT Essential Body of Knowledge (EBK) in 2012. Initial efforts focused on identifying core competencies and listing supporting topics, filling gaps identified in the GIS&T BoK, and leveraging significant participation and input from industry to add practicality. The EBK was further refined in 2019 to highlight five previously identified competency areas (GIS and analysis tools, remote sensing, programming and data management, cartography and visualization, and soft skills). Each competency encompasses a set of topics with learning objectives segmented by knowledge level into prerequisites, essentials, journeyman, and master. The resulting work is less comprehensive with respect to topical listings and learning outcomes presented in the BoK, but is aligned with professional certification and provides a basis for both academic codification and accreditation as well as workforce job classification.

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1. Darryl Murdock. "The Credentialing Landscape and USGIF Certifications." United States Geospatial Intelligence Foundation Academic Summit. Reston, VA. 2016.

The ideal state ultimately lies in the maturation of the GEOINT EBK as the underlying framework to address the larger need to articulate accredited curriculum with workforce parlance, classification, and credentialing systems. However, greater participation in subsequent revision cycles by those interested in workforce development is needed from government, industry, and academia. One could subsequently argue that without a specific mandate from an employer base—government, industry, or both—it will be difficult, if not impossible, to garner interest in further codifying the GEOINT profession.

The Future

Based on the aforementioned criteria (codification, segmentation, and a body of knowledge), GEOINT is making progress toward professionalization. The following areas, however, represent opportunities for GEOINT to further the professionalization process: better defining and explaining the relationship with existing professions

(i.e., surveying, GIS, intelligence); better advocacy and awareness of the public protection role of GEOINT (and GEOINT professionals); and defining the value proposition for GEOINT professionals.

USGIF launched a transparent, modular, and portable credentialing system and has created an ecosystem of accredited schools to help address the education and training component of a professional workforce, but these efforts are relatively young and require recognition by the greater GEOINT employment marketplace. Adoption of standardized job codes and descriptions, such as those listed above, is required to help gain further clarity.

The desired end state is a clear set of pathways for education, training, and consequent certification that helps both employers and employees match and advance industry goals. Above all, a clarion call for leadership that unites government, industry, academia, and the labor-management system is needed

to avoid fragmentation of the GEOINT industry into a world of competing subsets of spatial technologies and applications. Such a unified effort would result in a common and easily recognized identity for GEOINT that transcends what are currently entrenched and costly boundaries that lead to dissatisfaction and turnover in the workplace.

The groundwork essential for successful efforts that connect and coordinate codification, segmentation, and an improved body of knowledge are in place. A summit among stakeholder organizations would facilitate a renewed GIWIS-style investment and renew consensus efforts through a broader audience. Outcomes from such a summit would be useful in gaining funding support for further alignment and coordinated GEOINT workforce development efforts among government, industry, academia, and representative professional societies. ⮌

⮕ Generating Synthetic Data for Remote Sensing

By Dr. Jonathan Howe, NVIDIA; Dr. Aaron Reite, NGA; Dr. Kyle Pula, CACI; and Dr. Jonathan Von Stroh, CACI

The majority of modern image interpretation and analysis rely on deep neural networks (DNNs) due to their unparalleled accuracy, large capacity to differentiate between multiple object classes, generalizability, and relative simplicity to develop and apply new applications when compared to traditional computer vision methods. In recent years, DNN research has resulted in off-the-shelf classification, detection, and semantic segmentation algorithms, which, when properly trained, approach human-level or better performance in many imagery domains. However, large amounts of task-specific labeled training data are required to obtain these benefits. These data must exhibit the extent and variability of the target domain. Like other statistical models, DNNs do not extrapolate well in out-of-domain environments without

special care. For example, training a model to segment roads using images of North American cities, then deploying these models on images of European cities, will produce a less than ideal outcome. A basic obstacle to generalization for DNNs is that variations that seem obviously irrelevant to humans (e.g., different lane markings or agricultural practices) are perceived as completely alien to a DNN, leading to unpredictable results. Data augmentation during training (e.g., random mirroring, rotation, contrast and brightness changes, color balance, scaling, etc.) can partially alleviate these issues; however, more advanced methods are required for DNNs to generalize well to new environments.

To counter poor generalization, a number of methods rapidly create labeled datasets for training purposes, but

doing so efficiently, at scale, and with extensibility in mind requires careful thought. Developing a system using active learning methodologies deployed in collaborative environments can help annotators rapidly label data and create an operational capability, beginning from only a small amount of labeled data.[2] Many of these insights have been made in other fields, particularly with autonomous driving and health care, which require extra factors such as safety and interpretability.[3,4]

In addition to robust labeling, training, and a validation and deployment environment, more advanced techniques can maximize model accuracy within short time scales and with limited training data. For example, semi-supervised and unsupervised modeling can aid labeling

2. Ksenia Konyushkova, Raphael Sznitman, and Pascal Fua. "Learning Active Learning from Data." In *Advances in Neural Information Processing Systems*, pp. 4225-4235. 2017.

3. https://blogs.nvidia.com/blog/2018/09/13/how-maglev-speeds-autonomous-vehicles-to-superhuman-levels-of-safety/

4. https://developer.nvidia.com/clara

tasks while simulated environments can replace or supplement training and validation datasets. This article focuses on the latter approach: creating synthetic data workflows to increase model accuracy when labeled data are scarce.

Methods of Simulation

Geoffrey Hinton's 2007 paper "To Recognize Shapes, First Learn to Generate Images,"[1] greatly impacted the neural network and statistics research community. The paper lays out the steps to develop a multilayered neural network, methods to define loss functions, and the calculus to update model parameters to maximize model accuracy (known as back-propagation). In addition to this highly popular model training recipe, Hinton's work discusses modeling image generation to increase detection or classification accuracy further. In essence, understanding how to create images greatly benefits image interpretation and analysis (and vice versa).

There are two main approaches to simulate data, each with benefits and drawbacks: traditional computer graphics and data-driven generative models. Computer graphics use ray tracing and rasterization to render simulated scenes. This works particularly well in remote sensing and autonomous vehicle use cases where the basic primitives (buildings, roads, vehicles) and spectral conditions (viewing geometries, lighting angles, spectral content, atmospheric attenuation) are relatively simple and easy to model. For example, the Digital Imaging and Remote Sensing Image Generation (DIRSIG) modeling tool, developed at the Rochester Institute of Technology, provides methods to create physics-driven synthetic images for sensor development and to aid DNN model training.[2,3] Similar methods have been studied to render maritime vessels,

placing them into real imagery to vastly improve object detection metrics.[4] Autonomous vehicle and healthcare industries use rendering methods to generate simulated datasets to improve model accuracy, particularly when labeled datasets are scarce.[5,6] However, composing the scenes to be rendered can take time,
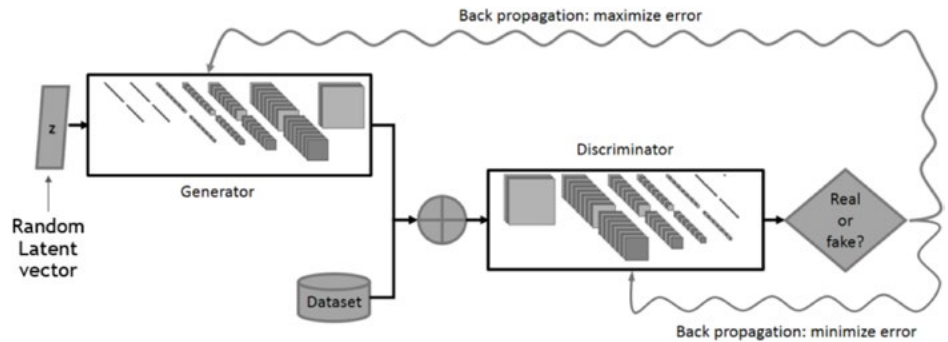

Illustration of the GAN framework: **D** (Discriminator) is alternately presented with images from **G** (Generator) and from the dataset. **D** is asked to distinguish between the two sources. The problem is formulated as a minimax game: **D** is trying to minimize the number of errors it makes. **G** is trying to maximize the number of errors **D** makes on generated samples. The curvy arrows represent the back propagation of gradients into the target set of parameters.

particularly if the target domain is diverse. Compared to the naive approach of gathering and labeling additional data, this approach trades human annotator work for illustrator work. In some cases, it may not be possible to perform this exercise without significant investment.

Alternatively, the generative approach to synthetic data views an existing corpus of real data as a collection of samples from the true distribution of real data, and tries to build a model that draws additional samples from this distribution. The generated samples (or imagery) resemble the data corpus and, if the model is trained correctly, can have very high levels of visual fidelity. This reduces the need to use the computer graphics approach of constructing and rendering objects of interest within scenes with realistic spectral conditions. However, if these parameters are known and available at training time, they can also be used to condition the model to control the generated output. Prime examples of

generative modeling, specifically using generative adversarial networks (GANs), include the works of Karras et al. for generating extremely high-fidelity imagery at high-resolution (in many cases fooling human examiners),[7] and Wang et al. for conditioning the GAN output at the pixel level using semantic labels.[8]

Generative Modeling vis GANs

A GAN consists of a pair of networks that, as the name suggests, compete against one another during the training phase. The generator network *G*, takes as input a random vector called the latent vector. If other metadata are available (lighting angle, etc.), then these values may be concatenated with the latent vector to condition the output. When generating new data, the network may be controlled via the metadata to create images with specific parameters. This latent vector is fed into a series of reshaping and de-convolutional layers to reconstruct and transform the vector into a generated image. The second network, the discriminator *D*, takes images from the real dataset (the data we are attempting to model) and the generated dataset and passes them through a series of convolutional and reshaping layers in a near mirror image of the generator network. It attempts to correctly predict

1. Geoffrey Hinton. "To Recognize Shapes, First Learn to Generate Images." *Progress in Brain Research*. 2007. no. 165: 535-547. https://doi.org/10.1016/S0079-6123(06)65034-6
2. http://www.dirsig.org
3. Sanghui Han,, Alex Fafard, John Kerekes, Michael Gartley, Emmett Ientilucci, Andreas Savakis, Charles Law et al. "Efficient Generation of Image Chips for Training Deep Learning Algorithms." In *Automatic Target Recognition XXVII*. 2017. vol. 10202, p. 1020203. International Society for Optics and Photonics.
4. Yiming Yan, Zhichao Tan, and Nan Su. "A Data Augmentation Strategy Based on Simulated Samples for Ship Detection in RGB Remote Sensing Images." *ISPRS International Journal of Geo-Information* 2019:8(6):276.
5. Josh Tobin, Rachel Fong, Alex Ray, Jonas Schneider, Wojciech Zaremba, and Pieter Abbeel. "Domain Randomization for Transferring Deep Neural Networks from Simulation to the Real World." In 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). pp. 23-30. IEEE. 2017.
6. A.F. Frangi, S.A. Tsaftaris, and J.L. Prince. "Simulation and Synthesis in Medical Imaging." IEEE Transactions on Medical Imaging. 2018:37(3):673-679. doi:10.1109/TMI.2018.2800298.
7. Tero Karras, Timo Aila, Samuli Laine, and Jaakko Lehtinen. "Progressive Growing of GANs for Improved Quality, Stability, and Variation." 2017. arXiv preprint arXiv:1710.10196.
8. Ting-Chun Wang, Ming-Yu Liu, Jun-Yan Zhu, Andrew Tao, Jan Kautz, and Bryan Catanzaro. "High-Resolution Image Synthesis and Semantic Manipulation with Conditional GANs." In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. 2018. pp. 8798-8807.

which images were generated by *G*, and which are real. These networks compete in a minimax two-player game: *D*'s objective is to correctly guess the generated versus real images, while *G*'s objective is to fool *D*. In the ideal outcome, *G* generates convincing synthetic images and *D* cannot determine if *G*'s images are real or not. During deployment, *G* is passed random latent vectors with conditioning metadata (if available) to create new plausible images. The discriminator is typically discarded.[9]

GANs have been used successfully in the healthcare sector, which has a large imbalance between healthy medical images and those containing unhealthy tissue or tumors. GANs can help reduce this imbalance through the modeling and creation of additional data.[10] In addition, when privacy concerns are an issue, GANs have been used to apply anonymity, creating synthetic data that lack personal information while still exhibiting the scan details of patients.[11]

Using GANs for Remote Sensing Applications

To train remote sensing DNNs using generative models for data augmentation, one must model both the imagery and the associated labels to a high degree of accuracy and fidelity. Researchers have made progress toward this by transferring image statistics from one domain, where there is an abundance of data, to the target domain that is similar in appearance and content, but with far fewer examples.

For example, Yun et al. use cycle-consistent generative adversarial networks to convert visible band data to infrared data.[12] Similarly, Benjdira et al. used the output of CycleGANs between visible
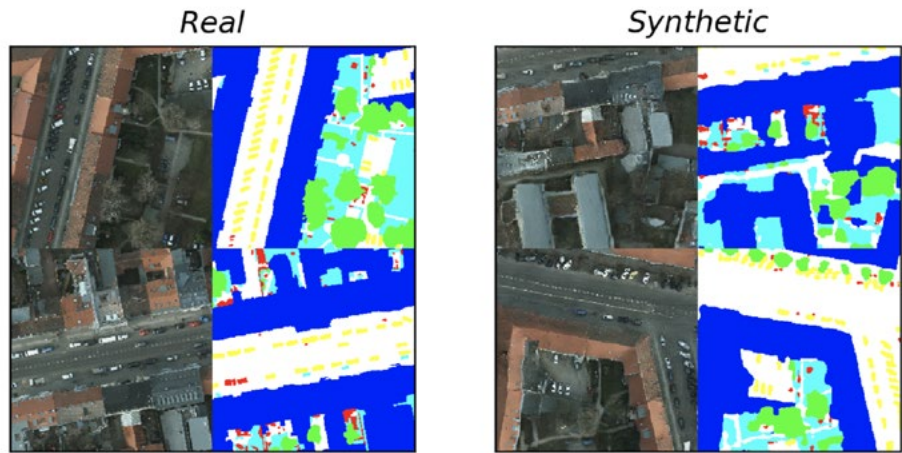

Figure 1. Real ISPRS Potsdam image and label pairs (left), and synthetically generated image label pairs (right). The synthetic segmentation masks were generated via ProgressiveGAN, and the synthetic imagery was generated via Pix2PixHD conditioned on the generated mask.

band and infrared data to significantly increase segmentation accuracy of remote sensing datasets.[13] Seo et al. transferred image statistics from real images into synthetically rendered imagery containing military vehicles to increase the overall image fidelity.[14] In each of these works, real data are used to augment synthetic data for object detection or segmentation model training.

In our recent work (Howe et al.), both the imagery and the labels are modeled together to create completely new labeled images, which we use to train an object detector.[15] To our knowledge, this is the first time such joint modeling has been attempted using GAN methods for any application area. Here, we use the International Society for Photogrammetry and Remote Sensing (ISPRS) 2D Semantic Labeling Contest—Potsdam dataset. This dataset consists of 24 segmentation labeled 6,000x6,000 pixel images collected at a 5-cm ground sample distance with six categories of land use types: impervious surfaces (white), buildings (blue), low vegetation (cyan), trees (green), vehicles (yellow),

and clutter (red). We use the methods of Karras et al. (ProgressiveGAN) and Wang et al. (Pix2PixHD) to model the spaces of segmentation masks and imagery conditioned on such masks, respectively.[16,17] Figure 1 presents examples of real and synthetic image and label pairs.

From a qualitative perspective, it is difficult to differentiate real from synthetic datasets. The Fréchet Inception Distance (FID) metric is commonly used to quantitatively measure how well generated data match the real data's distribution. Informally, FID tries to measure how different images are from real images when processed through a particular DNN trained on the ImageNet dataset. We observed that increasing the quantity of training data for the GANs resulted in an increased FID score—meaning that the generated images became less similar to real images when the quantity of training data was increased. This makes sense as GANs learn to interpolate between training images, which becomes more difficult as the number and diversity of training images increases.

9. Ian Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. "Generative Adversarial Nets." In Advances in Neural Information Processing Systems. 2014. pp. 2672-2680.

10. Felix Lau, Tom Hendriks, Jesse Lieman-Sifry, Sean Sall, and Dan Golden. "Scargan: Chained Generative Adversarial Networks to Simulate Pathological Tissue on Cardiovascular MR Scans." In *Deep Learning in Medical Image Analysis and Multimodal Learning for Clinical Decision Support*. 2018. Springer, Cham. pp. 343-350.

11. Edward Choi, Siddharth Biswal, Bradley Malin, Jon Duke,and Walter F. Stewart, Jimeng Sun. "Generating Multi-label Discrete Patient Records Using Generative Adversarial Networks." In Proceedings of the 2nd Machine Learning for Healthcare Conference.2017. PMLR 68:286-305.

12. Kyongsik Yun, Kevin Yu, Joseph Osborne, Sarah Eldin, Luan Nguyen, Alexander Huyen, and Thomas Lu. "Improved Visible to IR Image Transformation Using Synthetic Data Augmentation with Cycle-Consistent Adversarial Networks." In *Pattern Recognition and Tracking*. 2019. XXX, vol. 10995. p. 1099502. International Society for Optics and Photonics.

13. Bilel Benjdira, Yakoub Bazi, Anis Koubaa, and Kais Ouni. "Unsupervised Domain Adaptation Using Generative Adversarial Networks for Semantic Segmentation of Aerial Images." *Remote Sensing*. 2019: 11(11):1369.

14. Junghoon Seo, Seunghyun Jeon, and Taegyun Jeon. "Domain Adaptive Generation of Aircraft on Satellite Imagery via Simulated and Unsupervised Learning." 2018. arXiv preprint arXiv:1806.03002.

15. Jonathan Howe, Kyle Pula, and Aaron A. Reite. "Conditional Generative Adversarial Networks for Data Augmentation and Adaptation in Remotely Sensed Imagery." 2019. arXiv preprint arXiv:1908.03809.

16. Tero Karras, Timo Aila, Samuli Laine, and Jaakko Lehtinen. "Progressive Growing of GANs for Improved Quality, Stability, and Variation." 2017. arXiv preprint arXiv:1710.10196.

17. Ting-Chun Wang, Ming-Yu Liu, Jun-Yan Zhu, Andrew Tao, Jan Kautz, and Bryan Catanzaro. "High-Resolution Image Synthesis and Semantic Manipulation with Conditional GANs." In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition. 2018. pp. 8798-8807.

When using GAN-generated data to augment real training datasets, a similar trend is found. If only a small amount of data is available to train the GANs and an object detector, in this case, RetinaNet,[1] the relative increase in mean average precision (mAP) can increase by more than 10 percent, as compared to training with real data alone using standard data augmentation methodologies. For a practical comparison, this improvement is about 40 percent of the benefit realized by exhaustively labeling an additional 6000x6000 pixel image. As the number of training images is increased, the relative improvement in mAP decreases; until eventually this GAN augmentation method becomes detrimental. This pipeline is effective, but only when very little labeled data is available. If labeled data are abundant, it may not offer a benefit and could possibly hurt performance. However, for small amounts of training data, these methods can provide an additional boost in performance beyond traditional augmentation techniques.

Summary and Future Work

In some imagery domains, the computer vision tasks of classification, detection, and segmentation can be viewed as solved problems in the sense that, given plentiful, diverse, and well-labeled data, off-the-shelf techniques can now approach or even exceed human-level performance. Unfortunately, in practice, these data requirements often far exceed the volume, diversity, and fidelity of most labeled datasets. In addition, these off-the-shelf techniques typically don't hold up well to the highly imbalanced datasets that are the norm in many applications. These problems are compounded by the fact that techniques for transferring information from labeled data in one domain to another (often called domain adaptation) do not remotely approach human level performance but are an active area of research.

Aside from labeling more data, which can be costly or even impossible in some scenarios, the two main approaches to augmenting scarce data are synthesizing data by computer graphics and generative models. Both techniques have shown promise in remote sensed imagery but have a common shortfall: They optimize for photorealism instead of usefulness as training data. Other than human feedback changing hyper-parameters, neither approach attempts to use prediction accuracy as a training signal to improve the simulation. The situation is akin to students preparing for an exam, yet the teacher completely ignores exam performance in further curriculum development. In proper instruction, the curriculum is dynamically adjusted based on student performance. In machine learning (ML), this feedback loop, wired via gradient descent, is referred to as meta-learning. We anticipate that future advances in data synthesis for ML will come from unifying graphics and generative approaches in a meta-learning construct to directly optimize for the desired computer vision task, rather than photorealism. ⮌

⮕ Next-Generation GEOINT Systems—Influences and Needs

By Chuck Herring, AllSource Analysis; Dave Gauthier, NGA; Ed Kunz, Midwest Aerial; Jenny Yu, Kimetrica; Steven Truitt, Descartes Labs

Overview

The ability to collect, analyze, and use data about our environment is increasing every day. This abundance of capability and promise of continued growth are key elements in the resurgence of digital transformation across all sectors of industry, government, and private life. Engineering solutions for this world, especially when working with heavy and complicated remote sensing data, can pose unique challenges that call for new and innovative solutions. In this article, we inspect the roles of data collection, storage, management, analysis, and consumption as factors that drive designs.

Data Collection

Data collection has matured greatly from the era of black-and-white photography. Modern sensors, whether in ground, air, or space, cover the full electromagnetic spectrum with a variety of sensor types, and often can collect multiple modalities simultaneously, ranging from wide-area, low-resolution to small-area, high-resolution. These diverse options, combined with choices in the time domain from space-based periodic revisit, air-based on-demand collection, and ground-based constant collection, all create an incredibly rich set of data collection options to choose from.

Adding to the range of options, data can be collected in multiple different operating modes. Just in the aerial domain, for example, there are options to digitize historical film imagery, pre-flight selection of imaging sensor and telescope, and on-the-fly selection of a camera's operating mode. This data, once collected, must then be coupled with location information (i.e., GPS or inertial sensors). Selecting a level of processing and which algorithms to apply adds another decision layer. Finally, all of this collection optimization compounds with data transfer schemes that can include post-collection transfers, streaming collection, or targeted sub-collect delivery. Space- and ground-based collectors have a similar range of choices, although somewhat more constrained due to the environments they operate in.

As if the technical complications were not sufficient, the business model of a data collection campaign matters as well. At least in the aerial domain, post hoc sales of individual datasets from a data library represent a value of approximately 1 percent of new collection. While this number differs by collector, sensor type, and regime, the notion that data collection

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1. Tsung-Yi Lin, Priya Goyal, Ross Girshick, Kaiming He, and Piotr Dollár. "Focal Loss for Dense Object Detection." In Proceedings of the IEEE International Conference on Computer Vision. 2017. pp. 2980-2988.

is highly time-dependent remains constant. This poses both a challenge and an opportunity: If additional value can be extracted from entire historical collection libraries, data can be made more affordable and data collectors can expand into new business models. If it cannot, then the costs of storage and management can be overly burdensome, and the data collection world will remain bifurcated into targeted high-resolution and wide-area low-resolution.

Storage, Management, and Analysis Enablement

The eruption of cloud computing (and the renaissance of edge computing) has solidified one truth for the foreseeable future: High-performance IT design for complex problems will be dominated by the ability to centralize data. Additionally, the rate of growth of data collection capabilities is continuing to outstrip the ability of global communication networks. For small data volumes, this does not pose a substantial issue; however, for large-volume collection and use, there are two domains where this gap between collection and communication becomes evident.

When collecting heavy data at long standoff ranges, a narrow communications channel is often required to move from the sensor to a data center. Space systems are often constrained in this way, where the sensor is able to capture much more information than a communications link is able to handle. Alternatively, when analysis is spanning many types of collection or it takes place over a long time period, moving data to a common location for co-processing can be exceedingly taxing on even high-performance network systems. To dramatically simplify the issue, the root of both is a cost concern on how often expensive communications links are used.

From a data storage and management perspective, there are three potential solutions:

1. Heavy processing at or near the sensor to minimize comms.

2. Integration across data centers of convenience (inter-cloud).

3. Centralization into common data stores.

The first option, processing at or near the sensor, is always a good idea and is nearly always implemented to some degree. The challenges here consist primarily of size, weight, and power concerns when balancing preservation of signal (larger data size) with information extraction (larger power and size, potential to lose valuable data). At the end of the day, the ongoing proliferation of increasingly powerful computing units will lead to a state of equilibrium where sensors are producing compressed or extracted data of high value with minimal data loss.

The second option, integration across data centers, simplifies integration for sensor providers as a local data center can be used rather than identifying a global communications route. For data sources that are accessed locally or analyzed in isolation, this serves as a good choice. It strikes a balance between cloud computing power and communications network difficulty. This approach is particularly good for analysis of extremely large datasets, as the network performance within a data center due to colocation of storage and compute is orders of magnitude higher than crossing an internet backbone between data centers.

The third option, data centralization, is the only real choice when performing multisource large computations. While the upfront cost and difficulty to move data to a central location is higher than either edge or regional storage, the nature of multisource analysis means that data will be accessed multiple times to be computed in a single location. This means that if a regional data center is used, the data will be pulled multiple times over the internet rather than one single time for the initial centralization. Furthermore, this type of design benefits from the same intra-network latency reduction as the second option, but can cover multiple datasets.

For the foreseeable future, data collection rates will exceed communication bandwidth from the sensor to a high-bandwidth fiber connection, and analysis is continuing to grow in complexity and scale. Ultimately, it is a cost and performance question that will dictate whether regional or central management

is the best architecture, with centralization proving more effective if analysis is multisource and large-scale.

Analysis, Exploitation, and Data Science

Analysis, exploitation, and use of data science to solve problems can take myriad forms. For illustrative purposes, we look at two models that are near the extremes of what is possible:

1. Multiple-model assemblies for fully automated environment characterization.

2. Human interpretation of problems with high cultural and historical context requirements.

These two extremes share some similarities regarding the speed and scale of automation support, however, they also differ dramatically in the demands placed on underlying systems.

Developing multiple-model assemblies.
In developing multiple automated models to predict complex environmental and human processes, various datasets from different sources must be collated for preprocessing and normalization. For this kind of workflow to be scalable, there's a need to centralize storage and inventory for the satellite imagery, underlying truth data, and an interface platform to query the data collection in a consistent way. Federating out to multiple environments carries a price-and-performance cost that interferes with model iteration cycles. This approach solves the most common issue in working with remote sensing data: How to efficiently manage the data in a pipeline and develop a system that is deployable outside of a local environment and its dependencies.

From a modeling feature perspective, some key attributes for large-scale modeling are:

1. Worldwide spatial coverage, in particular coverage for rural and remote areas of interest.

2. Consistent temporal coverage.

3. Distributed processing to reduce the time to analyze vast areas.

When these three features are met, training and deploying automated models is quite feasible. For example, creating computer vision models to extract out human geography can be quickly iterated and deployed over continental scales when there is the combination of GPUs, consistent and multisource data, and scalable access. Almost as important as the computing environment in this scenario is the ability to respond quickly on iteration; systems that can reduce the cycle time from training to testing dramatically improve modeling efficiency. A platform that enables this human-to-human interaction in addition to performing large-scale computation is critical. Multiple-model assemblies are in essence the combination of multiple people's understanding of the world and conveying these perspectives to each other is critical.

Interpreting activity using deep contextual and cultural knowledge.

The far opposite of automated environmental modeling is the application of deep human knowledge of context and history as broadly as possible to understand particular goals and activities. This approach has always relied on a many-source approach to providing insights, with steps commonly known to this community such as finished geospatial intelligence. As human as this process is, it can still benefit greatly from large-scale data processing as artificial intelligence (AI) has been demonstrated to greatly reduce the search space and focus human analysis on true areas of interest.

Traditionally, analysts have had to make inferences when viewing imagery and disparate datasets, oftentimes requiring separate analysis techniques for each. Each person would be naturally limited by the pace at which these datasets could be joined as well as the pace at which potential targets could be evaluated. When data and systems are separate, this leads to a compounding challenge

as people are asked to both context-switch between systems and datasets while also transiting multiple locations, multiple times. The time involved just in mechanically walking through this process can be substantial, although the real challenge exists in maintaining attention and context through multiple sets of information. As the range of sensors and types of data increases, this problem can compound to the point where otherwise valuable data cannot be gainfully integrated in an analysis while maintaining reasonable timeliness.

Automation and integration of these sources is proving to be a fertile ground for improvement, however. Of special interest is the ability to place dynamic AI capabilities in the hands of analysts such that multiple data sources and techniques can be deployed on demand or pre-processed across a wide area for search-space reduction. As every analytic challenge is unique, the ability to adapt capabilities on the fly and have a near-real-time response from the system holds enormous potential for site identification and activity characterization. This human-in-the-loop approach to rapid system design has long been considered a valuable target, and recent capabilities benefiting from data centralization and configurable AI are making it reality.

The final consideration from an analysis perspective is that as AI and automation improve in the ability to perform inference of increasing complexity, the role of the human analyst becomes more important for both final product creation and information integrity validation. Even in an ideal world when there is a perfectly accurate automated model, translating this refined information into a product that can be consumed and acted upon will depend on a deep understanding of both the human problem and the supporting observation technology.

Organizational Integration

The digital transformation of organizations is a dominant trend for the next decade. What is observed of technologies and designs for the collection, storage, management, and use of multisource and large-scale data will directly impact the pace of transformation for organizations that depend on this information. Trade-offs exist between operational efficiencies designed for the user, the data storage solution, the data transport layer, and on-demand analytic computing power. Organizations need to determine which design trades are best for their own mission outcomes.

One factor that often gets overlooked is that organizations also have different user types: managers, analysts, and scientists, to name a few. One initial insight from integrating in large organizations is to optimize data environments and management systems more for the scientific requirements because that is where an organization can mine the most potential for creating new value. This translation from scientific discovery creates a competitive edge.

There has been an incredible push to move legacy capabilities to a cloud-native version. However, in the organizational push to migrate onto cloud environments and provide shareable data, a key capability has been left behind: multi-source analytics at scale. This requirement of people producing useful intelligence was formerly served by niche capabilities but must now be itself translated to a high-performance, scalable solution. This begs the ultimate question for geospatial system design: Going forward, will we evolve into hybrid-cloud architectures, duplicate data across multiple custom architectures, or see the pendulum swing back to more on-premises solutions?

Time will tell; there are compelling cases for each. ⬡

⊕ MARFRONT: Portuguese Coast Permeability Model for Illegal Sea Entries

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Immigration is and always has been a factor that shapes politics, economics, and cultures at an international level. In Europe, the number of irregular entries along the continent's external border reached a record high in 2014, registering around 280,000 migrants crossing the EU border illegally. As an EU member, Portugal has been very active in not only participating in joint operations, but also in the development of new methodologies for monitoring and detecting irregular migrants, mainly through the testing of drones from a Portuguese airbase in the southern part of the country (the Algarve).

At the national level, Portugal does not have a problem with immigration, but this article seeks to evaluate the Portuguese coast to determine its permeability to irregular entry via the sea. This evaluation was developed as a possible future tool that Portuguese border guards could use to identify the most critical areas along the Portuguese shoreline. Though it is not the case right now, Portugal could become the next country of entry for migrants leaving North Africa due to the ever-increasing levels of monitoring, detection, and overall security on the Mediterranean Sea.

Portugal's coastline is 943 kilometers long, but for this analysis, we are only taking into account the south and southwest coastline (the Algarve and Alentejo regions), assuming an individual trying to enter Portuguese territory from the North of Africa would try a disembark in this area.

Methodology

The permeability model, named MARFRONT, was developed by determining the friction levels an adult would encounter when entering Portugal through its coast. It is important to mention that friction and permeability levels are inversely correlated. The model was computed based on a Multicriteria Evaluation (MCE) and couples two methodologies developed for the EU by the Joint Research Centre (JRC) and the European Union Satellite Centre (SATCEN).

The methodology developed by JRC, called Model EU25,[1] had the objective of determining the permeability of land borders at a European level by combining three criteria that represented a group of variables and would directly influence the friction experienced by an individual crossing the border unlawfully by foot. On the other hand, the model developed by SATCEN in 2017, called the Geospatial Vulnerability Indicator (GVI),[2] is a model intended for the same purpose, but at a more local level.

The MARFRONT model is a coupling of both methodologies presented above in terms of techniques, variables, and criteria, but is adapted to the Portuguese reality using national data sources at a 30-meter resolution. It is important to note that data and information about the sea, mainly average sea conditions and depth, would be of great value for this model, but was not incorporated due to the simultaneous unavailability of data at our scale of analysis and time restrictions. Portugal is currently developing new geospatial products for the Portuguese sea that will be available in 2020, which could greatly improve this model.

Every criterion is a combination of variables that have been normalized by a reclassification based on a linear function that varies between 0 and 1, and directly influence border permeability. The weights defined for each criterion had an exploratory basis, with the goal of understanding how each criterion or groups of criteria impacted the outputs based on different scenarios.

Data

The data layers include:
- Railways (OpenStreetMap, 2019).
- Roads (OpenStreetMap, 2019).
- Land Cover/Use (Direção Geral do Território, 2015).
- Digital Terrain Model (Direção Geral do Território, 2015).
- Resident Population by Administrative Subsection (Instituto Nacional de Estatística, 2011).
- Border Control Points (BCPs) (Official Journal of the European Union, 2013).
- Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (National Oceanic and Atmospheric Administration (NOAA) 2019).

Border Permeability

In general, "permeability" is a term borrowed from the physical sciences, where it has the precise meaning of a process that measures the ease with which a fluid goes through a material. Boundary permeability is the product of the line characteristics (the outcome of legal, geographical, historical, and social factors) and the pressures on this line from people, goods, capital, ideas, and so on. The higher the permeability, the easier it will be to traverse that boundary. This term is often used in environmental studies, mainly geology. In this case, border permeability refers specifically to the factors that directly influence the capability of a human being to cross the border line.

Border permeability can transcend physical barriers and be alternatively identified by social integration, economic flow, or political relationships.[3]

In this article, we are determining the friction of the physical barriers that directly impact border permeability by creating and combining a group of criteria, defined by variables, in order to compute MARFRONT's different outputs.

1. N. Stephenne and M. Pesaresi. Spatial Permiability Model at the European Union Land Border. 2006. Joint Research Centre (JRC).
2. European Union Satelite Centre. Geospatial Vulnerability Service: Tier-1 Production Methodology, 1–13. (2017). (Task Reference: R17060 to R17064)
3. Cigdem Varol and Emrah Söylemez. Border Permeability and drivers Of CrossBorder Cooperation in the Turkish and EU Border Region. KnE Social Sciences. 2017. 1. 87. 10.18502/kss.v1i2.649.

The MARFRONT Model

With all variables normalized, four criteria were identified, each representing factors that influence the success of an adult entering Portuguese territory undetected through the coastline. These criteria are:

1. Security area.
2. Hide capability.
3. Communication network density indicator.
4. Terrain permeability.

The concept of mobility is a central issue when determining border permeability due to it being a factor that directly correlates with the success/failure of crossing the border undetected. Because of its importance, two of the criteria focus more on this issue: terrain permeability (TP) and communication network density indicator (CNDI). Both these criteria were created and developed based on SATCEN's methodology. The CNDI, which varies between 0 and 1, determines how easily and quickly an individual can reach a road or railway from the coastline. This was determined by the density of communication networks and distance of each road and railway segment from the border. The higher the CNDI, the closer to the border and the denser the communication networks.

On the other hand, TP determines how easily an individual crosses the terrain based on slope, land use, and roads. The criterion provides an overview of how permeable the terrain is accounting only for geographic parameters. Land use and slope was classified from 1 to 5 based on empirical levels of difficulty defined in SATCEN's methodology. The CNDI was used in this criterion as a variable to represent the access to roads and railways from the coast.

Hide capability is the criterion that determines where along the coast are the best or worst areas to hide from detection when entering irregularly. To determine this criterion, we used the same approach as in Model EU25, which assumed an adult, to evade detection, would want to avoid densely populated areas, flat areas, and lights at night, and would try to seek areas with more vegetation.
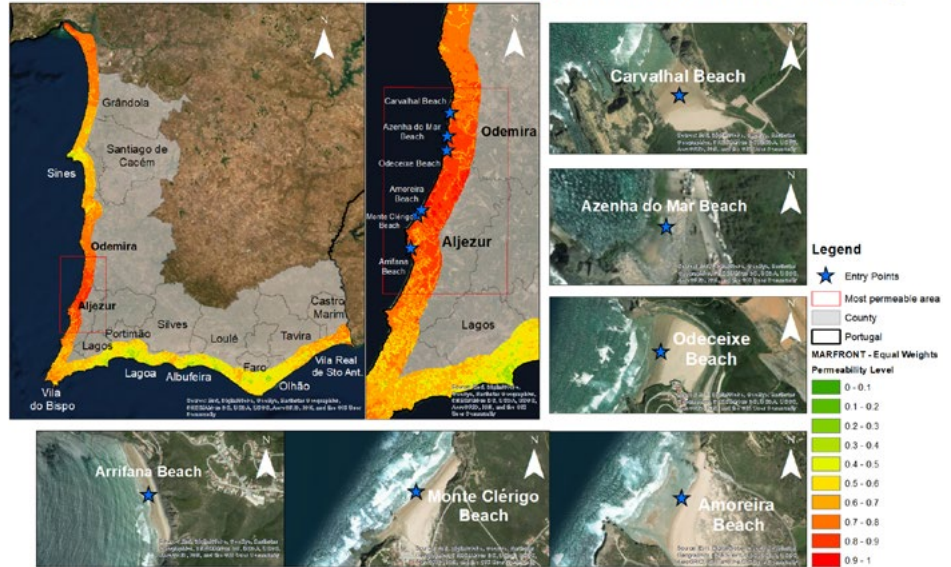

Figure 1. Detailed results for the MARFRONT model for the equal weights case.

Security in area is an important criterion because it heavily influences the friction levels regarding border permeability along the Portuguese coast. This criterion is based on the location of the border control points (BCPs) and the cost distance from these to the coastline, based on the variable TP already determined. This means the closer the entry point is to the BCP, and the more permeable ground there is en route to the entry point, the higher the level of security will be.

All criteria were combined in a weighted linear combination (WLC) with empirically assigned weights based on different scenarios that could determine more importance to one criterion compared to another. Table 1 shows the four different weight combinations for each output.

Criteria Weights (%) in Each WLC Output

	CNDI	TP	Hide	Security
Equal Weights	25%	25%	25%	25%
Security	25%	25%	15%	35%
CNDI & TP	35%	35%	15%	15%
CNDI & Hide	35%	15%	35%	15%

Table 1. Criteria weights in each weighted linear combination (WLC) output.

Results and Conclusion

Based on the MARFRONT model and its variations, represented by assigning different weights to the criteria, we observed the statistics listed in Table 2 regarding the different outputs.

Area of High and Low Permeability (%) by Output

Alentejo Litoral (Soutwest Coast)		
	High Permeability (0 to 0.5)	Low Permeability (0.5 to 1)
Equal Weights	94.75 (546 Km²)	5.25 (30 Km²)
Security	71.90 (414 Km²)	28.10 (162 Km²)
CNDI & TP	99.76 (575 Km²)	0.24 (1 Km²)
CNDI & Hide	95.43 (550 Km²)	4.57 (26 Km²)

Algarve (South Coast)		
	High Permeability (0 to 0.5)	Low Permeability (0.5 to 1)
Equal Weights	76.95 (919 Km²)	23.05 (275 Km²)
Security	35.36 (422 Km²)	64.64 (772 Km²)
CNDI & TP	98.27 (1173 Km²)	1.73 (21 Km²)
CNDI & Hide	79.51 (949 Km²)	20.49 (245 Km²)

Table 2. Results, in percentage and square kilometers, for high permeability and low permeability by multicriteria evaluation.

This led us to draw the following main conclusions:

- The four variations used in the multicriteria analysis are a good representation of the range of permeability that the same variables allow us to represent.

- In general, the Alentejo coast is more permeable than the Algarve coast (Figure 1).

This led us to choose the Equal Weights methodology for a more local and detailed analysis, because it represents a better distribution of the data along our area of interest. Of all the combinations, this

was the one that had the most balanced spatial representation at an administrative level. Building a model remains a choice between realism (mimics reality), precision (quantitatively correct), and generality (application to different places).[1] So, for this model, the importance given to each criterion can be adjusted to the reality of each scenario.

Based on this output (Figure 1), and at a more detailed level, we were also able to conclude:

- The most permeable regions of Coastal Alentejo are in the north of Grândola County and in the south of Odemira County.

- The most permeable regions of Coastal Algarve are in the north of Aljezur County, which forms a continuous area of high permeability with Odemira County in southern Alentejo.

- Within this continuous area, six potential entry points were identified where an individual could easily make the transition from sea to land.

In short, according to the MARFRONT model, the southwest Portuguese shoreline is the most permeable of the region under analysis. Within these areas, we identified the six most critical sections within the most permeable areas. Although these are not the only possible points of entry, they're the easiest paths through the natural cliff barrier that surrounds most of the Portuguese coast, and therefore are assumed to be the main points of entry of an irregular immigrant within this area.

Lastly, it is important to note that the introduction of BCPs along the coastline has an increasing effect on the friction represented spatially, and thus reduces permeability. This is obvious in Table 2, where the Algarve, because of the higher number of BCPs, has a larger area of low permeability when more weight is given to the security factors. At a European level, with the recent migration crisis, the monitoring and control of the entry points for irregular migrants has been one of the main factors that has contributed to the

diminishing flow of this type of activity.

Apart from physical constraints like barriers and BCPs, we should also consider Europe's footsteps, for example, creating legal corridors for desperate individuals who have the right to claim asylum so they can do so without risking their lives. This is an effective way of channeling irregular migration in a controlled manner. This is not only safer, but more efficient, because it creates a mechanism through which member states can legitimately and easily control and monitor increased migration.

If Portugal ever experiences a migration crisis, like other EU members have in the past and present, the first step would be to implement more monitor-and-control capabilities at critical points of entry. The MARFRONT model represents a potential first step in identifying the critical areas and entry points, and could thus enable the introduction of new BCPs to monitor and control the irregular flow of people. ⮌

⮑ STEM for GEOINT: Building Our Tradecraft's Future

By Corinne Jorgenson, Vice President of Strategy/Eos AI Science; Christine MacKrell, USGIF; and Rachel Zimmerman, CyberPatriot

Science, technology, engineering, and mathematics (STEM) education is a hot topic among parents and educators and an increasingly important component of workforce development. The future of our workforce and national strategic advantage relies on a pipeline of highly qualified STEM professionals.

A critical element of inspiring students to pursue careers in STEM fields is providing them with an understanding of how STEM concepts learned in school translate to real-world applications and, by extension, careers.

The GEOINT industry is growing, and with it, so too is the demand for talented GEOINT professionals; the future of our tradecraft rests on the shoulders of students in school today. To encourage

engagement with a GEOINT career path, experiential educational programs designed for K–12 students maximize opportunities to foster a student's interest and skills in GEOINT-related disciplines from a young age.

Growth in STEM Disciplines and Need for GEOINT Professionals

The Geospatial Industry Is Growing
The geospatial industry, spanning commercial and defense sectors, is a hotbed of rapid innovation and growth. According to economic trend analysis, the industry is projected to grow from $339 billion in 2018 to $439.2 billion in 2020, a 13.8 percent compound annual growth rate.[2] This growth rate even outpaces

the industry's growth between 2013 and 2017, which was 11.9%.[3] While the U.S. currently leads the geospatial market, economic analysis reveals that the Asia-Pacific region is the fastest growing.

This growth is driven by increased demand for GNSS devices, location data, map content, and geospatial-related solutions and services. Advances in artificial intelligence (AI) and big data compound this aggressive demand by influencing the cost of acquiring data, the number of users, and speed to intelligence. The market for geospatial imagery analytics, including video analytics and security, climate modeling, and remote sensing, is also rapidly expanding. Experts anticipate a compound growth rate of 30 percent from 2017 to 2024 within this segment.[4]

1. R. Levins. "The Strategy of Model Building in Population Biology. American Scientist. 1966: 54(4):421-431.
2. *GEOBUIZ: Geospatial Industry Outlook & Readiness Index.* Noida: Geospatial Media and Communications, 2019, 21.
3. Ibid.
4. "Geospatial Imagery Analytics Market to Record Impressive Growth, Revenue to Surge to US$21,200 Million by 2024." Zion Market Research, last modified May 15, 2018, https://www.zionmarketresearch.com/news/geospatial-imagery-analytics-market

A significant resultant challenge, already experienced by many organizations within the industry, is a dearth of qualified talent when compared with demand.

The Growing Need for GEOINT-Related STEM Professionals

Across the nation, STEM-related occupations expanded rapidly through the early 2000s, growing by 10.5 percent between 2009 and 2015 and creating 817,260 new jobs.[1] Within STEM, GEOINT-related fields experienced similarly significant growth. The growth rate across STEM fields was much higher than the net growth rate in non-STEM occupations during that same period, which was only around 5.2 percent.[2]

GEOINT-related jobs are expected to continue to grow, consistent with growth in the geospatial industry. The Bureau of Labor Statistics (BLS) expects a 19 percent increase in traditional GEOINT jobs (cartographers and photogrammetrists) by 2026. Technological innovations in areas like AI and big data for GEOINT are also driving rapid growth in job opportunities for related professionals. In late 2017, LinkedIn listed "machine learning engineer" and "data scientist" as the top two emerging fields in the job market, respectively.[3] According to the BLS, the field of mathematical science, which includes subjects related to big data and data science, is expected to expand 27.9 percent by 2026.[4]

The growth in these GEOINT-related STEM disciplines elevates the need to prepare students to meet the needs of the future workforce.

Best Practices in GEOINT STEM Education

To meet the growing demand for GEOINT professionals, we must prepare the next generation of STEM professionals with the skills and expertise required to continue driving innovation. Several challenges and factors drive the form and scale these educational experiences must take, including diversity of populations, learning styles, student age, and educational readiness.

A key component of preparing students for a GEOINT-related career is teaching creative and analytical problem-solving beyond rote and didactic instruction. According to Kantor, Pricope, and Wang, differentiated teaching styles maximize a student's opportunities to learn and engage with their STEM education.[5] Another key component of successful STEM education is introducing students to a wide range of disciplines from a young age, before students self-select into career paths. The art of STEM education is understanding a specific student population and responsively employing the most rewarding educational practices and techniques, both in and out of the classroom.

Inspiring STEM education encourages students to explore their curiosity through experiences, experimentation, observation, and conceptualization. Because of its often conceptual nature, a best practice in STEM-related education is experiential and activity-based learning, which allows students to work within their individual learning styles and bridge the gap between theory and practice. In fact, many professional-level programs include field experience to build an individual's skills and quickly facilitate the move from theory to practice.[6] Especially when teaching massive-scale and conceptual domains related to GEOINT trades, experiential learning helps to link what students learn in the classroom with real-world capabilities.

Cases in GEOINT-Focused Experiential Learning

In recent years, forerunners in GEOINT education have started to design experiential-based learning opportunities for K–12 students, such as STEMulate St. Louis and Mini-Open Innovation Center (OIC) curriculum.

STEMulate St. Louis

At USGIF's 2018 Tech Showcase West (now the Geospatial Gateway Forum), the Foundation launched STEMulate St. Louis, a K–12 STEM event at Saint Louis University with a GEOINT focus. Geared toward K–12 students as well as their families and teachers in the St. Louis, Mo., area, this free event provided opportunities to learn more about geospatial STEM topics through interactive and exciting activities.

In STEMulate's inaugural year, sponsors including BAE Systems, Boundless (now Planet), Esri, Harris (now L3 Harris), the National Geospatial-Intelligence Agency (NGA), and the St. Louis Science Center led hands-on demonstrations related to thermal imaging, binary coding, contour and elevation mapping, aerial imagery analysis, and more. USGIF led geographic activities on its Portable Planet, a 35x26-foot floor map designed for students to walk on and engage with geospatial concepts.

Hands-on activities like these are shown to be critical in growing and sustaining interest in STEM subjects among K–12 students. According to the U.S. Department of Education, a strong STEM education is one that emphasizes hands-on experience and interaction with STEM professionals, both of which are accomplished by STEMulate St. Louis.[7]

The Mini-Open Innovation Center

In collaboration with USGIF and CyberPatriot, the nonprofit Riverside

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1. Stella Fayer, Alan Lacey, and Audrey Watson. "STEM Occupations: Past, Present, and Future," last modified January 2017. https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf
2. Ibid.
3. Rachel Bowley. "The Fastest-Growing Jobs in the U.S. Based on LinkedIn Data," last modified December 7, 2017. https://blog.linkedin.com/2017/december/7/the-fastest-growing-jobs-in-the-u-s-based-on-linkedin-data
4. Michael Rieley. "Big data adds up to opportunities in math careers." Bureau of Labor Statistics Beyond the Numbers, last modified June 2018. https://www.bls.gov/opub/btn/volume-7/big-data-adds-up.htm.
5. Camelia Kantor, Narcisa Pricope, and Susan Wang. "Discipline-Based Education Research: A New Approach to Teaching and Learning in Geospatial Intelligence." *The State and Future of GEOINT*. 2018: 22.
6. Janet Eyler. "The Power of Experiential Education." *Liberal Education* 95. no. 4. 2009.
7. Courtney Tanenbaum. *STEM 2026: A Vision for Innovation in STEM Education.* Washington, D.C.: U.S. Department of Education. 2016, 1.

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Figure 1. Students and their families learning about how machines can learn to recognize human shapes, WashingtonExec STEM Symposium, March 30, 2019. Image Credit: Riverside Research.

Research developed an experiential learning curriculum with space-based GEOINT as a unifying context. The curriculum connected STEM concepts with GEOINT-supporting disciplines such as plasma physics, AI and machine learning (ML), radar engineering, and trusted systems (cyber). Using the organization's own research labs as a model, they connected these ideas with a theme called the "Mini-OIC." In the activities, students participated in hands-on demonstrations that provided concrete experiences to help them understand abstract concepts and their relationship to GEOINT following modern experiential learning theory.[8]

First, students built a handmade miniature "satellite" from household objects like paper plates and cardboard tubes while learning the basic concepts of space-based GEOINT. Then, the students worked through a series of experiments and instruction, exploring potential applications of AI, optics, plasma, cybersecurity, and radar in relation to the satellite and to GEOINT.

Components of the Mini-OIC curriculum include:

- **AI and ML:** an introduction to how machines can be trained to recognize and classify movement. In this demonstration, students performed specific dances that were observed by a computer vision algorithm and classified.

- **Radar Engineering:** an overview of how radar works and visualizes objects. This portion of the curriculum allowed students to use an actual, functioning radar built from a coffee can.

- **Plasma Physics:** an introduction to the most prevalent state of matter and how its properties might affect satellites in space.

- **Trusted Systems:** an introduction to cybersecurity and why systems must be protected from cyber threats.

The three organizations offered the curriculum STEM fairs/events in the Washington, D.C., and Dayton, Ohio, regions, which are free to attend and enable broad participation. As of 2019, components of the Mini-OIC curriculum have been provided to more than 5,200 students.

What's Next in GEOINT-Focused Experiential Learning?

Programs like STEMulate and the Mini-OIC are models for GEOINT-focused experiential learning, but alone are not enough. A key next step in embedding GEOINT within STEM and building the tradecraft's future is further curriculum and program development. GEOINT-related STEM curriculums should foster sustained (rather than episodic) interest in GEOINT subjects among K–12 students.

STEM programs that provide students with hands-on experience are needed to spark interest in students at a young age. A 2012 study conducted by STEMconnector and My College Options showed that of the nearly one million high school freshmen interested in STEM majors and careers, 57.4 percent of those students will lose STEM interest by graduation.[9] More programs that offer experiential learning are needed in order to help students maintain their interest in STEM fields.

Many teachers do not have a background in geospatial or GEOINT disciplines and typically lack the free time to research and implement new educational activities that do not fall strictly within their standards of learning. This gap is where organizations with trade-related subject matter expertise are critical to successfully bringing geospatial concepts to the classroom.

Role of the Tradecraft Community

The responsibility to prepare the future of the GEOINT workforce is incumbent on the community itself. Both within and outside the classroom, partnership among government organizations like NGA, educational nonprofits like USGIF and the Air Force Association's CyberPatriot, and industry representatives like Riverside Research, Esri, Planet, BAE, and L3 Harris is required to connect STEM with trade expertise. The future of the GEOINT workforce is strengthened through collaboration in programs like STEMulate and the Mini-OIC; it is incumbent upon all

8. Alice Y. Kolb and David A. Kolb. "The Kolb Learning Style Inventory – Version 4.0: A Comprehensive Guide to the Theory, Psychometrics, Research on Validity and Educational Applications." Experience Based Learning Systems, Inc. 2013. https://web.archive.org/web/20170516224452/http://learningfromexperience.com/media/2016/10/2013-KOLBS-KLSI-4.0-GUIDE.pdf
9. *Where are the STEM Students?* Lee's Summit, MO: myCollegeOptions. 2012, 4.

Figure 2. A student tests a computer vision algorithm at the March 30, 2019, WashingtonExec STEM Symposium. Image Credit: Riverside Research.

stakeholders to create, identify, and use these partnerships to train the workforce of tomorrow.

Figure 3. A student at USGIF STEMulate learns in a flight simulator, October 9, 2019. Image Credit: USGIF.

Industry

GEOINT professionals have a vital role to play in growing geospatial interest within STEM and education more broadly. They are crucial in the curriculum development process as subject matter experts, and USGIF is utilizing GEOINT professionals from industry as well as academia to develop their lesson plans. However, the tradecraft community is also needed to implement this curriculum in the classroom. Teachers cannot be expected

to lead geospatial lessons on their own; Fleming, Janocha, and Machado state: "Collaborating with educational partners is often a matter of expressing an interest in doing so. Educators rarely have a surplus of useful support, and our industry needs to invest in the next-generation talent."[1] GEOINT professionals will need to step up as community volunteers to work as liaisons between the classroom and industry.

Educational Nonprofits

Educational nonprofit organizations are uniquely positioned to create and implement programs aimed at helping students gain and maintain an interest in GEOINT STEM fields.

USGIF is currently developing geospatial curriculum and lesson plans that are hands-on, engaging for students, and manageable for K–12 teachers to implement. Through these plans, USGIF incorporates volunteers from GEOINT professions in the classroom to serve not only as subject matter experts but also as an example of what a career in GEOINT can look like.

Programs like CyberPatriot, the National Youth Cyber Education Program, have demonstrated that their hands-on National Youth Cyber Defense Competition is inspiring students to study STEM fields. The 2018 alumni survey conducted by the program reports that high school students surveyed indicated they will pursue a two- or four-year education program plan to study cybersecurity (20.6 percent), computer science (24.6 percent), or another STEM field (30.3 percent).[2] More than 91 percent of survey respondents indicated their participation in CyberPatriot somewhat (53.6 percent) or significantly (37.7 percent) impacted their career and educational goals.[3]

Outside of the tradecraft community, educational standards organizations set models that can be helpful for fostering curriculum engagement and adoption. The nonprofit Achieve coordinates the Next Generation Science Standards (NGSS) objectives, which "focus on creating system-wide thinking and modeling lessons intended to facilitate K–12 learning and critical thinking skills."[4] NGSS has the potential to create a generation of thinkers who will become the adaptable professionals the STEM and GEOINT workforce needs.

Building Our Tradecraft's Future

The GEOINT Community is rapidly growing and this growth is projected to continue through the next decade. Consistent with this growth, increasing demand for talented GEOINT professionals requires an intentioned focus on building the workforce of tomorrow. It's critical to establish a pipeline of talent by engaging young students. Experiential learning techniques are demonstrably effective in sustaining interest and facilitating deeper learning and critical problem-solving.

Recently, members of industry have begun collaborating to create GEOINT-specific

1. Steven Fleming, Brad Janocha, and Luis Machado. "The Fluid Employee: Adaptability in the 21st Century." *The State and Future of GEOINT*. 2017: 20.
2. "Alumni Survey Report 2018." Air Force Association's CyberPatriot National Youth Cyber Education Program, last modified June 2018. https://www.uscyberpatriot.org/Documents/Fact%20Sheets/2018%20Alumni%20Survey%20Report_180719.pdf
3. "Alumni Survey Report 2018." Air Force Association's CyberPatriot National Youth Cyber Education Program, last modified June 2018. https://www.uscyberpatriot.org/Documents/Fact%20Sheets/2018%20Alumni%20Survey%20Report_180719.pdf
4. Steven Fleming, Brad Janocha, and Luis Machado. "The Fluid Employee: Adaptability in the 21st Century." *The State and Future of GEOINT*. 2017: 20.

educational opportunities, and more of the same are needed. It is incumbent upon the entire tradecraft community, including the government, industry, and educational sectors, to create and support these initiatives to position the workforce of tomorrow and sustain our national strategic advantage. ☝

☝ St. Louis: The Evolution of America's Emerging Geospatial Center of Excellence

By Andy Dearing, Spatial STL Advisors; Patricia Hagen, Ph.D., T-REX/Geosaurus; Dr. Dwayne Smith, Ph.D., Harris-Stowe University; Kenneth Olliff, Saint Louis University; Jim Alexander, St. Louis Regional Economic Development Alliance

This past November, Vice Admiral Robert Sharp, Director of the National Geospatial-Intelligence Agency (NGA), joined military, governmental, civic, and community leaders in St. Louis, Mo., to officially break ground on Next NGA West, the agency's new, state-of-the-art facility that will be constructed just north of downtown.

While the city had a growing geospatial sector prior to the 2016 announcement by NGA that St. Louis would be the home of Next NGA West, the selection helped catalyze the development of a true geospatial ecosystem that has grown rapidly through a major push by governmental, civic, economic development, academic, and community organizations.

This geospatial ecosystem is poised for even stronger growth, resulting in no small part from NGA's announcement at the GEOINT 2019 Symposium in San Antonio that it will declassify 20 percent of its new campus—opening up unprecedented opportunities to collaborate with academic, commercial, and other innovation partners.

NGA's decision to build its $1.75 billion Next NGA West campus in St. Louis continued the decades-long partnership NGA had with the city. It also spurred much of the activity driving St. Louis' emergence as the nation's center for geospatial excellence.

One development in this process that will promote additional entrepreneurial growth and create more demand for geospatial talent was the establishment of creative public/private initiatives, such as the Partnership Intermediary Agreement (PIA) between NGA and Missouri Technology Corporation (MTC). This formal agreement, a first for both NGA and MTC, creates strong connections among NGA, Missouri's thriving start-up community, and the state's world-class higher education institutions.

Specifically, the PIA will allow small businesses and educational institutions to license NGA's intellectual property. Under the agreement, MTC will identify start-ups and universities with an interest in licensing and further developing NGA's patented technology, opening more doors to opportunity for entrepreneurs and researchers across the state, and driving demand for more talent.

The Challenge and Opportunity

The challenge and opportunity faced by St. Louis is how to strengthen and expand a talent pipeline to meet the growing needs of NGA and the larger geospatial ecosystem, which is expanding into relationships with other sectors of the regional economy, including transportation and logistics, agricultural technology, cybersecurity, financial technology, health care, and biotechnology.

As NGA Deputy Director Dr. Stacey Dixon said in reference to recruiting talent: "The future [of geospatial] is going to be a lot more in and out of both industry and government, and I'm excited about that, but it's a different model. The opportunity there is great."

This rapidly growing geospatial ecosystem requires talent, and, through multiple coordinated endeavors, St. Louis is developing the pipeline to meet the needs of the GEOINT Community today and well into the future.

Strategic Planning for the St. Louis Geospatial Ecosystem

As St. Louis' geospatial ecosystem looks to continued growth and further develops a talent pipeline to meet future needs, several strategies are being developed. St. Louis' institutions and backbone organizations are not just looking to increase the number of people qualified to work in geospatial technology, but are also seeking to ensure that:

• Workforce training addresses jobs for the future, not just for the next few years.

• Geospatial technology is connected to the needs of other thriving sectors in the region.

• Cutting-edge research is encouraged and promoted within the region.

• Thought leadership is established and recognized within and outside the region.

• Opportunities for entrepreneurs and innovators to start up, stand out, and stay in the region are highlighted and supported.

• Equity and inclusion are key components in the region's talent development initiatives.

Meeting these objectives is critical to ensure a thriving ecosystem that will serve the St. Louis community and our nation into the future.

A Multilayered Approach to Develop a Talent Pipeline

The geospatial jobs of the future will not resemble the career-long paths with NGA or private companies that have existed in years past. Developing talent with traditional and nontraditional approaches is necessary to train job-ready workers to

join the geospatial workforce of today and tomorrow.

To further develop its talent pipeline and make sure that workers are prepared for the changing employment landscape, St. Louis is taking a collaborative, multilayered approach that includes:

• Work by civic organizations to attract geospatial businesses and talent to St. Louis right now.

• Programs created at the region's institutions of higher learning to prepare students for jobs in the geospatial sector in the near future.

• NGA's partnership with local schools to develop curricula for middle and high school students who will join the workforce in five to 10 years.

• Work by St. Louis organizations to develop and engage young geospatial professionals—especially women—already working in the geospatial industry to connect them to the ecosystem and empower them to serve as ambassadors to attract new talent.

Traditional and Nontraditional Approaches

To emerge as the nation's center for geospatial excellence, St. Louis has engaged in a collaborative effort that has brought governmental, civic, business, academic, and community institutions to the same table to speak with a unified voice and work toward the same mission. In many ways, so many different entities coming together with common purpose is emblematic of the traditional and non-traditional approaches being employed to train the workers of today and tomorrow. Three examples of this non-traditional approach can be seen in Gateway GIS, LaunchCode, and Geospatial 101, while the programming developed by the St. Louis region's academic institutions exemplifies a more traditional approach.

GatewayGIS provides a free GIS and STEAM skill-building pipeline for low-income students via education, career development, and entrepreneurship. The purpose of GatewayGIS is to offer opportunities that are not ordinarily made available to students in underserved, urban, low-income communities, such as in the city of St. Louis and East St. Louis/Madison County, Ill. Activities in which GatewayGIS participates are career awareness, internships, entrepreneurship, GIS summer boot camps (grades 6–8), and K-5 teacher professional development. Key partners of GatewayGIS are NGA, USGIF's St. Louis Area Working Group (SLAWG), and area colleges and universities.

LaunchCode is a national nonprofit that provides accessible pathways to tech careers and helps companies find skilled, new tech talent from all backgrounds and walks of life. It assists jobseekers to enter careers in tech through integrated training, apprenticeships, career coaching, and job placement services. LaunchCode has begun adding new capabilities to bring its coding and developer training to the region's growing geospatial talent base. NGA partnered with LaunchCode to create a new program in GIS mapping technology to train developers for the agency. The program aims to place more than 100 developers at NGA in the next few years.

Geospatial 101 is a joint program by Saint Louis University and NGA in which experts explain to the public what geospatial is, explore the importance of geospatial in our everyday lives, and look at ways geospatial is being used to address issues important to the region like healthcare disparities and disease. By helping educate the public on the practical and important everyday uses for geospatial technology, the program looks to inspire more people to take interest in the field, and possibly consider it as a career path.

Programs at institutions of higher learning train current students for geospatial jobs in the near term, which is a critical component of strengthening St. Louis' pipeline of ready talent. In the past decade, area institutions of higher learning have increased their focus on geospatial programming. According to the National Research Council, from 2010 to 2016, there has been a 58 percent increase in degrees and certificates awarded in geospatial fields by St. Louis-area post-secondary institutions.

Colleges and universities across the St. Louis region have wholeheartedly embraced St. Louis' geospatial future, establishing degree and certificate programs, including:

• **Saint Louis University:** Geoinformatics and Geospatial Analytics Concentration within Ph.D. for Integrated and Applied Sciences; Policy and Geospatial Analysis Concentration, Ph.D. Public and Social Policy; Geoscience, Master's and Ph.D.; Master of Science in Geographic Information Science; GIS Certificates at Graduate and Undergraduate levels; and Computational Geospatial Science, Undergraduate Minor; United States Geospatial Intelligence Foundation (USGIF) GEOINT Certificate in process.

• **Southern Illinois University Edwardsville:** Master of Science in Geography; Undergraduate Major and Minor in Geography; experiential learning opportunities through the Laboratory for Applied Spatial Analysis.

• **University of Missouri-Columbia:** Master of Arts in Geography; Geospatial Emphasis in Online Professional Master's in Data Science & Analytics; NGA Onsite Program in Geospatial Data Science & Analytics with Certificate and Master's pathways; Undergraduate Major in Geography; GIS Certificate; USGIF Geospatial Intelligence Certificate.

• **Missouri University of Science and Technology:** Bachelor's, Master's, and Ph.D., Geological Engineering.

• **Washington University:** Certificate in Geographic Information Systems.

• **Harris-Stowe State University:** Geography curriculum, with new offerings around Geospatial and STEAM Community Outreach; Certificate in Urban Agriculture with an emphasis on Geographic Information Systems Research.

St. Louis Area Working Group (SLAWG) is the only working group of the USGIF that is geographically defined. The institutions above are all active members in its many sub-committees, which coordinate regional initiatives in research and development, workforce

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development, and K–12 engagement. The SLAWG is broadening its coordination with USGIF and is starting initiatives to engage more students and young professionals in regional geospatial conferences, including Geo-Resolution at Saint Louis University, USGIF's Geospatial Gateway Forum, and the GEOINT Symposium.

Preparing for the Future: NGA Partners with Schools

NGA has developed a partnership with local schools to develop curriculum for students, inspiring them to work in the geospatial sector years from now and providing pathways from a high school degree to traditional and nontraditional programs that can support their career path development post-high school.

Beginning in the 2017–2018 academic year, and in concert with the authorities in Department of Defense's (DoD's) Partners in Education (PIE) program, NGA has executed a multiyear, multiphase, outcome-based program that fosters greater geographic literacy, inspires interest in STEM education, and advances GIS skills, progressively equipping regional K–12 students for higher education and careers at NGA or in STEM-related businesses.

NGA employees help with PIE program initiatives that include classroom instruction, tutoring, pen pal programs, science fairs, hackathons, geocaching, career fairs, GeoDays, GeoPlunge tournaments, and giant map activities.

The PIE program demonstrates not only NGA's commitment to developing the local talent pipeline by advancing STEM education in local schools throughout St. Louis, but also its commitment to be a good neighbor and member of the communities its current and future facilities call home.

Developing and Engaging for a More Diverse Workforce

Tapping into the talent already working in St. Louis is another critical part of strengthening and expanding the regional talent pipeline. These networks are critical to attracting new talent

and demonstrating that for geospatial professionals and people looking to enter the field, St. Louis is a place where they can start up by joining a new entrepreneurial geospatial venture or starting their own, stand out with the backing of a collaborative network of like-minded professionals, and stay as a result of the supportive community and lower cost of living and running a business.

Examples of St. Louis' efforts to engage young professionals include:

- **Geosaurus Unleashed** is a happy hour and discussion series revolving around the geospatial and location intelligence community. It is sponsored by T-REX, the advanced information technology innovation center in downtown St. Louis, as an element of its new Geosaurus Geospatial Resource and Innovation Center. T-REX is home to many geospatial start-ups and companies as well as an NGA innovation site.

- **The St. Louis chapter of USGIF's Young Professionals Group (YPG)** hosts events including happy hours, panel discussions, and other informal networking opportunities to help build a sense of community among area geospatial professionals.

- **GeoSTL** is an informal Meetup group that brings together developers, geographers, students, hobbyists, data scientists, and anyone else regardless of skill level to create maps and learn. They host mapathons, networking events, field collection outings, and group projects in collaboration with regional organizations.

- The first **St. Louis Regional Women in Geospatial Technology Summit** was held in June 2019 at T-REX and brought together more than 120 participants from industry, academia, and NGA to hear presentations and discussions and to begin developing an ongoing network of female geospatial professionals.

These networks are a necessary component of talent pipeline development, bringing together like-minded individuals who can connect to share new ideas and employment opportunities.

GeoFutures: The Strategic Roadmap for St. Louis Geospatial Cluster

To bolster St. Louis' rapidly growing geospatial sector and develop a strategic plan for the future, leaders from the region's public and private sectors have come together behind a new initiative called **GeoFutures**. GeoFutures will be guided by an advisory committee that features a broad and diverse group of leaders from the region's public, business, civic, and academic sectors.

GeoFutures is ensuring that this diverse group of players will collaborate as a community, working together to create a shared vision and align the efforts of many people and institutions toward the common goal of making St. Louis the nation's geospatial center of excellence.

The GeoFutures initiative is committed not only to growth, but to equitable growth. The initiative will prioritize linking the work to opportunities that help achieve racial equity by, among other possibilities, reducing barriers to career pathways, particularly for African-American residents.

Among the leaders who will advise the GeoFutures Initiative are Letitia ("Tish") Long and Robert Cardillo, who served as Directors of NGA from 2010–2014 and 2014–2019, respectively.

Conclusion

While St. Louis had a strong geospatial sector prior to being selected as the home of Next NGA West—geospatial technology is responsible for 27,053 in total employment impact and $4.9 billion in total regional economic activity—the 2016 announcement of the city's selection helped catalyze the growth of a true geospatial ecosystem.

By taking the next step—the GeoFutures Initiative's coordinated and strategic planning process—the region is bringing together the leaders and organizations that will help St. Louis develop the talent pipeline and economic, governmental, civic, academic, and community infrastructure necessary to rise to the challenge of sustaining St. Louis' emergence as the nation's center of geospatial excellence. ⮌

⤷ Geospatial Intelligence Revolution in Insurance and Risk Management

By David J. Alexander, Ph.D., Science and Technology Directorate, U.S. Department of Homeland Security; Roger Grenier, Ph.D., Global Resilience Practice, AIR-Worldwide; Talbot Brooks, MSc., Center for Interdisciplinary Geospatial Information Technology, Delta State University; David Cunningham, Earth Intelligence, MAXAR Technologies

Global security, public safety threats, and disaster risks are expanding and increasing in more diverse and complex ways. Some of this increase can be attributed to changing climate, population growth, increased urbanization, aging infrastructure, environmental damage, terrorism and radical Islam, and social fragmentation and inequality. What is most alarming about the rapidly expanding hazards and threats landscape is the scale, magnitude, and frequency of which these events are occurring. For example, the U.S. public safety community responds to over 300,000,000 emergency 911 calls per year and growing. And these numbers do not include the additional demands for response that occur during natural disasters or large-scale incidents.[1]

Over the last three years, nearly three in four Americans have been impacted by disasters (hurricanes, floods, fires, and violent extremism) either directly or indirectly through an immediate family member or friend. From 2016–2018, 37 states and two territories received presidentially declared disasters. These disasters cost the U.S. taxpayer a cumulative total of $457 billion and 3,663 lost lives. The vast majority of these costs were incurred from damage to public buildings, infrastructure, and natural ecosystems. These statistics, when taken alone, are disturbing, but when coupled with other statistics are even more alarming. They show that U.S. disaster risks are not just of concern to lives and property, but also to our way of life as they threaten the fiscal solvency and fabric of the nation. These trends are taking an unprecedented physical, financial, and psychological toll on America, affecting our global, national, and economic security in unprecedented ways. How do we reverse these trends without technological advancement and innovation? How are the key sectors such as insurance and risk management adapting to the rapid pace of the evolving hazards and threats landscape and technological innovation? And what is the current and future role of GEOINT in disaster insurance and risk management?[2]

Convergence of GEOINT with Insurance and Risk Management

GEOINT has emerged as a uniquely valuable tool for public safety, homeland security, disaster management, and risk reduction. It is helping our Communities to become more fully protected, connected, and aware as well as economically secure. GEOINT is at the center of a growing convergence between technologies such GIS, remote sensing, artificial intelligence (AI), IoT, high-performance computing, platforms such as small sats, drones, in situ sensors, and smart devices, and techniques in data science, digital forensics, sentiment analysis, forecasting, and predictive analytics. The new GEOINT economy is providing a means for better allocating our scarce resources to achieve optimal advantage and address some of our most pressing global, national, and regional challenges.

The insurance and risk management sectors are playing a more prominent and important role in managing disaster risks. GEOINT is underpinning much of the new innovation and expansion that is occurring in these sectors (commonly referred to as InsurTech). InsurTech refers to the use of technology innovations to disrupt and transform the current insurance industry that is heavily entrenched in traditional indemnity insurance models. As the needs of consumers and suppliers in the insurance and risk markets are becoming more complex, GEOINT is becoming more ubiquitous, responsive, easier to access, and useful. This is allowing InsurTech the ability to optimize traditional indemnity offerings (more refined actuarial tables and risk profiles, automated claims processing) and to introduce new products and services, such as customized policies (endorsements for earthquake, flood, etc.), event-driven coverage (parametric insurance), dynamic pricing based on observed behavior (pay-by-the-mile auto insurance), and micro-indemnity insurance for recreational activities (i.e., drones, skydiving, etc.).

Traditional Insurance

At this point, you're probably scratching your head and thinking, "Insurance and GEOINT? What are these guys talking about?" So, let's take a moment to explain, keeping a focus on asset-related insurance only. Under traditional indemnity insurance, policyholders pay a premium for a fixed level of coverage that pays for the actual loss incurred from an incident or peril (i.e., fire), after a claim is investigated and processed, to get the policyholder back to the same as before the event. For indemnity offerings, insurers typically use generalized actuarial tables and risk profiles to spread their risk and reduce exposure.[3] They also rely on field adjusters and detailed, onsite claims investigations that are both costly and time-consuming before authorizing payouts—areas prime for innovation. This is where GEOINT comes in. GEOINT technologies are helping optimize indemnity offerings by enabling insurers:[4]

- To produce more refined actuarial tables and risk profiles to spread their costs and risk using more timely and higher resolution demographic and property information from foundational geospatial data (the closer you are to the risk, the higher your premium).

- To offer incentives for risk adverse behavior to employ dynamic pricing

1. David J. Alexander. "The Critical Need for Federal Public Safety and First Responder Science and Innovation." *International Public Safety Association Journal.* February 2019. 3rd edition. 36-58.
2. David J. Alexander. "Building Resilience for Communities and Infrastructure Through Geospatial Intelligence." Keynote speech at GeoInsurance USA, Hoboken, NJ. June 11-12, 2019.
3. Michael W. Elliott. "Rethinking the Limits of Parametric Insurance." *Insurance Journal.* September 24, 2019.
4. Corinium Global Intelligence. Proceedings from Geoinsurance USA., Hoboken, NJ. June 11-12, 2019.
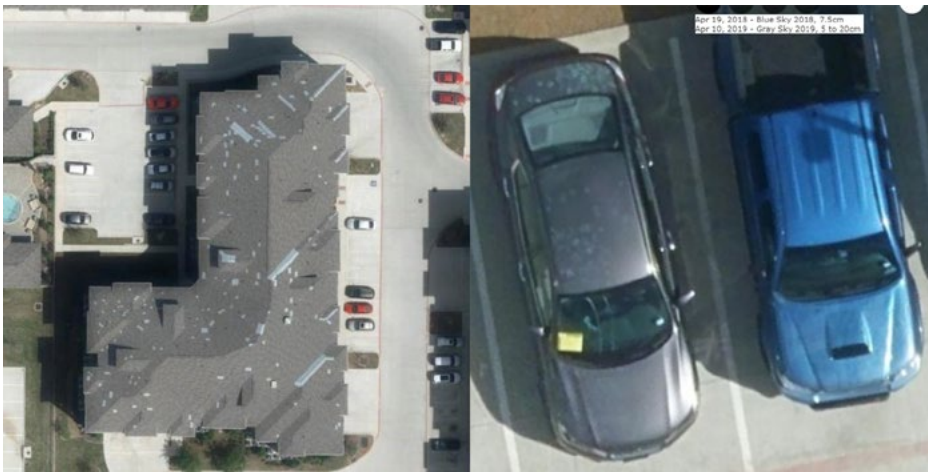
Figure 1. High-resolution aerial imagery of hail damage to buildings and automobiles. Hail damage is shown as light gray-blue pixels in the two images. This data is used to validate claims and determine the extent of damage. Image Credit: Geospatial Intelligence Center, National Crime Insurance Bureau, 2019.

models that reward good behavior (i.e., safe driving, less driving), using observational data from sensors like GPS.

- To issue on-demand policies for recreational activities based on type of activity, location, and duration (i.e., recreational drone liability coverage).

- To automate claims processing and inspection using high-resolution geospatial data combined with time-sensitive imagery services from aerial and space assets (i.e., validating roof damage from hailstorms) to streamline valid payouts and detect fraud.

While these advances are notable, traditional indemnity insurance still leaves policyholders with a protection gap from deductibles, excluded perils or terms, financial risks from business interruption or additional living expenses, moral hazards, or "Acts of God." This is why most insurance professionals view parametric insurance as a complement and not a replacement to indemnity insurance.[5] It is also what makes parametric insurance one of the most exciting trends in InsurTech. Parametric insurance provides an opportunity to close those gaps, and also a much larger protection gap facing U.S. taxpayers—losses from assets such as public buildings, infrastructure, or natural ecosystems. These assets have long been viewed as uninsurable and represent the costliest disaster losses to U.S. taxpayers and the public treasuries.

Parametric Insurance

What is parametric insurance? According to Andre Martin from SwissRe Corporate Solutions, parametric insurance is a policy that "covers the probability of a predefined event happening instead of indemnifying actual loss incurred."[6] It requires a trigger and payout, while traditional indemnity insurance requires a claim and inspection. Andrew Singer described it this way in his 2019 article in *Risk Management* magazine titled, "The Evolution of Parametric Insurance": "With parametric insurance, you avoid lengthy claims investigations—basically, an index is triggered, a payout is made, no questions are asked, there are no disputes."[7]

How does parametric insurance work? Parametric insurance uses a trigger to initiate a payout mechanism that is related to a scenario that is based upon an objective measure. The basic criteria for an insurable trigger are a scenario that is fortuitous, can be modeled, and related to a threshold parameter that can be measured to initiate payout. By design, parametric insurance is the embodiment of GEOINT, blending geospatial and remote sensing observations and modeling to supply the threshold trigger for a parametric policy. Common GEOINT triggers include the U.S. National Weather Service Hurricane Storm Forecast Models, USGS National Seismic Alerts, European Commission Stream gauge flow levels, Singapore National Environmental Agency (NEA) Pollutant Standard Index, and the Spanish Global Drought Monitor Index.[8]
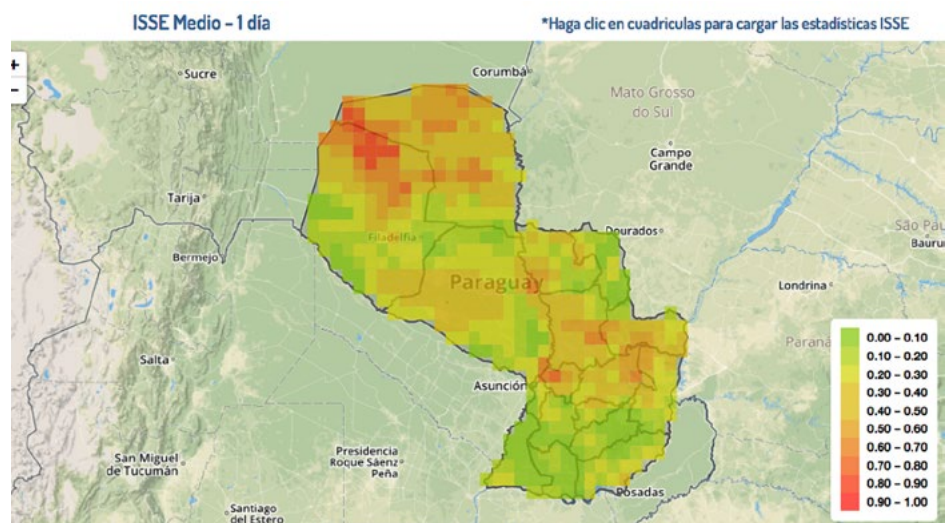

Figure 2. Weather-based insurance index for Paraguay; estimated values are for January 28, 2018. Areas in green indicate wetter soils, while yellow to red areas indicate regions where crops are subjected to some degree of water stress. Image Credit: https://www.fomin.org/es-es/PORTADA/Noticias/article-details(es-ES)/ArtMID/19154/ArticleID/12946/Innovative-weather-index-insurance-help-small-growers-in-Paraguay-mitigate-climate-risk.aspx

5. Bethan Moorcraft. "What Is Parametric Insurance?" *Insurance Business Magazine*. October 29, 2018.
6. Andrew Martin. "10 myths about Parametric Insurance." SwissRe Corporate Solutions. August 23, 2018.
7. Andrew W. Singer. "The Evolution of Parametric Insurance." *Risk Management Magazine*. April 1, 2019.
8. Andrew Martin. "What Is Parametric Insurance?" SwissRe Corporate Solutions. August 1, 2018.

The Louisiana School Board is an early adopter of parametric insurance. Under the basic terms of their coverage through SwissRe, the Louisiana School Board receives an automatic payout of up to $1.25 million if a named storm produces sustained winds of 80 miles per hour for at least a minute without any strings attached, like those associated with federal disaster aid. Parametric insurance is not limited to natural disasters, it can also be applied to human-made disasters like terrorism. Gallagher Insurance, Risk Management and Consulting has a created a parametric solution for terrorism called Public Sector Terrorism Plus. The Gallagher website describes the product as a unique terrorism insurance and risk modeling product that insures against foreseeable acts of terrorism that occur within the borders of a public entity or within a defined radius of an asset (facility). The product can include coverage for "traditional physical damage insurance, business interruption insurance (including cover for non-damage), terrorism liability insurance, denial of access (including non-damage), chemical, biological, radiological, nuclear (CBRN) attacks, or excess protection for higher limits on non-damage cover" according to the Gallagher website.

The Alianza del Pacifico Catastrophe Bond Case Study

The insurance and risk management sectors are not just limiting their innovations to core insurance lines, they are also exploring other areas of opportunity, such as disaster financing using catastrophic bonds that rely on GEOINT.

In recent years, catastrophe bonds have emerged as an effective risk transfer strategy and an important vehicle to attract capital market funding to insurance risk. A catastrophe bond is a financial instrument which transfers risks (generally from natural disasters) from the issuer to investors. In return for a coupon payment, investors assume the risk of a specified catastrophe occurring. Should a qualifying event occur, investors lose all or a portion of the principal invested, and the issuer receives those funds to cover losses.

Catastrophe bonds are typically issued by insurance companies as part of an overall risk management program. However, public entities and development banks have also issued bonds, with the latter often in developing countries to support reconstruction efforts following disasters.

The Alianza del Pacifico Catastrophe Bond project is one example.[1] The World Bank (International Bank for Reconstruction and Development) issued multiple bonds that collectively provide US$1.36 billion in earthquake protection to Chile, Colombia, Mexico, and Peru. Central and South America are among the most seismically active areas in the world, and the provision of emergency funds to the member nations will have significant benefit to the resilience of the participating nations in the wake of an earthquake event.
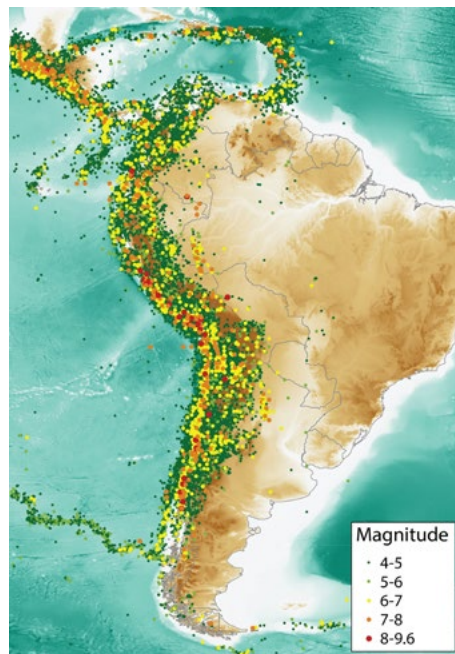

Figure 3. South America has a long history of seismic activity, featuring some of the strongest earthquakes on the planet. The map shows all earthquakes of magnitude 4.0 and larger known from the historical record (1541-2014). Image Credit: https://www.air-worldwide.com/Publications/AIR-Currents/2015/Modeling-Seismic-Risk-in-South-America--Five-Years-After-the-2010-Maule-Earthquake/

A unique aspect of the bonds is the innovative "cat-in-box" trigger mechanism. In this case, the trigger design involved dividing the national territories into grids, and then defining and assigning an appropriate magnitude and depth threshold for earthquakes to each square (box). Should an earthquake strike, real-time information from U.S. Geological Survey (USGS) is used to determine if its magnitude was greater than the threshold magnitude of the box in which it occurred. If it is, the cat bond will pay out. The program has worked as designed—a bond triggered following a magnitude 8.0 earthquake that struck Peru in May 2019, resulting in a $60 million payout to the Peru Ministry of Finance to aid reconstruction efforts.

GEOINT assets played a critical role in ultimately facilitating that payment. First, as noted above, population, land use, and other infrastructure data help establish the exposure at risk. Second, seismographic networks provided critical data on historical seismicity while Earth deformation data from GPS stations provide measurements of strain rates; together, these allow a "catalog" of potential future events to drive the catastrophe model. And, finally, earthquake data from the USGS provides critical information on the magnitude, epicenter and depth of the event in real time, providing a consistent, transparent, and trusted source of intelligence on which the transaction depends.

Possibilities Are Limitless

What becomes evident from analyzing current and emerging trends in insurance and risk management is that much of the innovation occurring in InsurTech is not possible or feasible without GEOINT. GEOINT is transforming insurance and risk management across the public and private sectors, enabling coverage for assets previously thought of as uninsurable, delivering solutions for closing the protection gap, and driving economic growth and expansion of the GEOINT, insurance, and risk management sectors. GEOINT is powering the evolution of parametric insurance and

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1. Claire Pontbriand, Mesut Turel, and Molly J. Markey. "Modeling Seismic Risk in South America: Five Years After the 2010 Maule Earthquake." AIR-Worldwide: A Verisk Company. February 19, 2015.

catastrophic risk models which are among the most significant developments in risk management and insurance over the last 30 years. Aided by increased computational power and high-quality, high-resolution, and timely GEOINT datasets, probabilistic simulations from these models are allowing stakeholders to quantify exposures, measure risk potential, and manage financial consequences. These models are becoming critical tools in combating the threat of natural and human-made catastrophes and are powering a revolution in the risk management and insurance industries.

Munich Re estimates global insurance premiums will nearly double by 2030 from about $3.5 trillion to $6.4 trillion.[2] Over this same time horizon, there is similar growth expected in disaster mitigation as FEMA plans to start issuing about $500 million per year in pre- and post-disaster mitigation and risk reduction grants.[3] This economic growth and technological revolution in the insurance and risk management sectors will undoubtedly create opportunities across the GEOINT Community for academia to educate and train the next-generation workforce, for the public sector to advance science and technology through further investment in basic and applied research, and spur industry to continuously deliver innovative technology and solutions. ⊕

Empowering Innovations and New Solutions by Expanding the GEOINT Workforce Through University, Industry, and Government Partnerships

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Challenges Faced by the GEOINT Community to Meet the Supply and Demand of GEOINT Requirements

The current state of geospatial intelligence (GEOINT) revolves around massive amounts of data, and a scarcity of trained professionals and effective tools to efficiently access and synthesize intelligence to support decision-making, especially in the cleared environment. TS/SCI-cleared geospatial professionals can be difficult to find, especially given the expanding demand for these skill sets across military, government, and private organizations. This has led to large staffing gaps across the cleared GEOINT Community. Moreover, even though many GEOINT workflows consist of laborious QA/QC procedures that soak up time and resources, analysts find it difficult to integrate new and innovative tools that could reduce overall labor into their workflows, if they can do it at all. In addition, there is still no viable pathway to integrate education and industry-based skills in cleared environments other than agency-sponsored internships. This forces the majority of GEOINT tradecraft to come directly from the military, which limits exposure, ideas, and innovation that could be gained from a more diverse workforce and puts a further strain on the supply of analysts who fit government requirements, not to mention the fact that it presents a real barrier to entry for non-cleared geospatial professionals.

GEOINT is a horizontal market that can fill vertical demands in almost any field, yet the average person or many businesses that could benefit from the integration of GEOINT into their workflows do not know what GEOINT is. This fact was made more apparent recently when Esri, one of the largest industry leaders in geospatial technology, used the term "location technology" in its robust national advertising campaign, because they determined the public simply would not understand the term "geospatial intelligence." GEOINT has a marketing problem; and in order to fulfill evolving GEOINT market needs and requirements currently and in the future, the size and diversity of the workforce will necessarily need to increase, which means more people ought to know what GEOINT is and the multiple benefits it can provide. Educational institutions can play a significant role in improving the visibility of GEOINT and employability of broadly trained GEOINT professionals, especially if aided by government and private industry—but therein often lies a disconnect in communication and collaboration we hope to explore with this contribution.

Aside from the communication and collaboration disconnect among academia, government, and industry, one of the major challenges in bridging the education and training (professional development), tradecraft, and workforce needs triad composed of academic, government, and industry players stems from an artificial supply-and-demand constraint on the skills and abilities of GEOINT analysts. The slow pace or lack of ability to integrate new tools, lack of public insight into the GEOINT Community, and recruitment into the field hamstringed by restrictive contracting requirements further exacerbate the supply-and-demand issue for GEOINT. While we are not necessarily highlighting a novel issue, we believe that closer connections and creative partnerships among academia, government, and industry could contribute greatly to addressing current challenges in GEOINT.

In August 2018, University of North Carolina Wilmington (UNCW) earned USGIF Collegiate Accreditation in GEOINT and has since been working closely with government partners to establish effective and mutually beneficial internships and collaborations to allow students to receive the hands-on training needed to succeed in the job market. Specifically, we established a three-credit, 120-hour internship with the U.S. Army Corps of Engineers (USACE) Wilmington District that provides students

2. MunichRe. Insurance Market Outlook. MunichRe Group. April 30, 2019.
3. Elizabeth Zimmerman. "BRIC Expanding the Concepts of Federal Pre-Disaster Mitigation." *Government Technology* Magazine. September 25, 2019.

with training in both GIS and imagery analysis in support of various USACE projects. More recently, we created similar internships with private industry as well as research and development (R&D) collaborations with state government entities that we are leveraging to improve student success, diversification, and alignment with evolving workforce needs. The former, an internship program that started in May 2019 with Wilmington-based GEOINT company Geo Owl LLC, has led to the employment of several UNCW students, while the latter R&D activities with the North Carolina Department of Transportation resulted in a $300,000 contract that is training and employing both undergraduate and graduate students. Throughout this process of more closely aligning university curricular offerings and research agendas with government and industry demands—both in terms of student training and R&D outputs—a few crosscutting issues emerged that further underscore the need to establish creative and collaborative multi-stakeholder partnerships.

Solutions for Expanding the GEOINT Workforce and More Effective Integration Among Training, Tradecraft, and Workforce Development

The triad of education (university), training (government and private industry), and tradecraft development (collaborative R&D among all three) should be managed to ensure that educational programs are aligned with developments in government and industry standards while maintaining a high level of academic rigor. As big data becomes bigger, faster, and more varied, and automation continues to replace manual tasks, GEOINT analysts will need to build new skill sets to empower their abilities for intelligence synthesis. They will need to understand a wide range of solutions to include open-source options and be able to integrate them into customer spaces. They will need to be able to program automated analyses and understand where the gaps in automation occur, correct data gaps, and ensure decisions are made solely on accurate information. Connecting the dots among education, training, and tradecraft development through flexible

and adaptive curricular and training offerings can contribute to ensuring these transitions can take place successfully.

Furthermore, to bridge the gap between GEOINT supply and demand, there ought to be concerted efforts among universities, industry, and government to better market the capabilities of GEOINT professionals and provide legitimate pathways from K–12 to GEOINT subject matter experts (SMEs). One avenue to increase understanding of educational requirements relative to workforce needs is for government to encourage these types of partnerships in contract negotiations with industry. In turn, this incentivizes industry to build and maintain long-term relationships with universities and ensures a stable talent pool that is familiar with GEOINT. Universities can make a larger impact on industry and government missions by being more involved with GEOINT operations. Typically, universities play relatively small roles as reachback or training support on some of the most robust GEOINT operations in the world. However, to have a more nuanced understanding of GEOINT demands and contribute more effectively toward marketing and increasing GEOINT awareness, universities should partner with industry and provide liaisons in the form of GEOINT research analysts who serve the dual functions of enhancing mission operations and driving educational requirements. The government should consider incentives for the inclusion of university subcontractors as part of contracting requirements, similar to requirements for small businesses.

Another similar and parallel avenue to increase understanding of educational requirements relative to workforce needs is to encourage these types of partnerships in contract negotiations directly with industry. In turn, this incentivizes industry to build and maintain long-term relationships with universities and ensures a stable talent pool that is familiar with GEOINT. As such, from an industry perspective, government acquisitions officers should consider the real market value for these skills and award contracts that are priced

proportionally to executable levels by working more closely with industry to empower innovative methods for solving problems. More vendor-defined solutions that integrate services with toolsets enable and incentivize industry to build better tools.

Government should consider a broader range of contract types, to include performance/metric-based incentives and institute rules for goal setting that act as elevators of innovation. GEOINT analysts now have a plethora of options as businesses are starting to realize the benefits of having those skill sets on board, and new GEOINT sensors and assets are continually deployed, putting massive constraints on the talent pool. By exploring new, nonrestrictive pathways to GEOINT careers, the community would allow and empower professionals to provide the right solution and develop tradecraft via university partnerships, internships, and other professional development avenues. For example, many government requirements list a Military Occupational Specialty (MOS) as necessary to fill GEOINT analysis positions. This requirement disables industry's ability to build, train, and mature a workforce to specifically suit the needs of the government. If a professional has years of GEOINT experience, the educational background, and the proven behavioral characteristics, then he or she shouldn't be hindered from enhancing the GEOINT mission and gaining access to this professional field. Likewise, many contracts contain degree requirements that have little to nothing to do with actual GEOINT skill sets. For example, on one contract with many GEOINT labor categories, the government listed a bachelor's degree as equivalent to six years of experience, regardless of major. This is misaligned with most GEOINT missions and places even more nuanced constraints on talent acquisition.

Conclusions and Pathways Forward for More Effective Integration Among Training, Tradecraft, and Workforce Development

To conclude, we reflect on current, future, and evolving GEOINT workforce trends and how educational institutions that offer GEOINT degrees and accreditations

can and should shift business as usual to support these evolving demands. Major GEOINT challenges include tackling ever-increasing data volumes, supply-and-demand imbalances of skill sets and trained professionals, a lack of proper GEOINT marketing, and hamstringed tradecraft development due to restrictive contracting requirements.

To address challenges with the exponential growth in data volume, velocity, and variety, we propose incentivizing innovation by requiring robust, vendor-defined solutions as well as industry/university partnerships in GEOINT-related acquisitions. This would subsequently drive further competition and lead to even more innovative solutions to address pressing GEOINT challenges. For example, a simple shift in contract requirements from full-time equivalents to outcome- or performance-based requirements leads to heightened competition and increased funding for R&D.

To address workforce talent pool and GEOINT visibility challenges, we propose new solutions for more effective GEOINT marketing and branding through concerted efforts by government, industry, and academic institutions. For example, to expand the potential interests in GEOINT for youth, we can explore working with celebrities, social media influencers, and other broadly recognized figures to proselytize GEOINT. In addition, we can improve GEOINT storytelling

for current and historical events by providing the GEOINT perspective with engaging videography, visualizations, and professional success stories.

To address hamstringed workforce development, one possible solution is for universities to acquire facility clearances; universities should gain access to SCIF spaces for unique GEOINT training and initiate clearance investigations for highly qualified students. They can work closely with the U.S. National Geospatial-Intelligence Agency, the military, and industry to closely mimic real-world operations and even solve real-world, classified GEOINT problems. Another solution is to work toward the removal of misaligned and restrictive MOS or non-GEOINT degree requirements for personnel on GEOINT contracts.

Lastly, to address all three challenges, we propose the development of regional GEOINT centers of excellence where academic institutions, governmental, and private organizations can work together in creative idea incubators to develop sustainable, flexible, and mutually beneficial collaborations. There are many locations outside of Washington, D.C., that have large GEOINT workforces, including California, Texas, North Carolina, Florida, and Missouri. Regional centers of excellence act as incubators of GEOINT innovation through solution-focused competitions, GEOINT Community gatherings, professional

development opportunities, and joint R&D initiatives among academic, private, and government institutions. They can encourage the recruitment of students in early career stages and allow for knowledge exchanges among faculty, government officials, and industry that can launch unique and successful enterprises that go beyond standard internship programs. For example, North Carolina has a large GEOINT Community consisting of three USGIF-accredited academic institutions, military bases performing GEOINT missions (Fort Bragg and Camp Lejeune), and state government agencies that are heavily reliant on GEOINT. A North Carolina-based center of excellence in GEOINT integration, as a starting point for a regional center of excellence in GEOINT, would bridge these communities into a common GEOINT purpose, provide creative opportunities for cross-sector solutions and interactions, and power innovative solution development for GEOINT as a whole. Given the mutually beneficial outcomes of such a regional initiative, the leadership team would necessarily be composed of representatives from each community that would work under the guidance of USGIF and NGA on actionable items that can begin to address the challenges in integrating education, training, and tradecraft development in GEOINT. ⮌

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⮌ Creating an Integrated, Multi-Source, Accurate, Trusted, and Immersive Cognitive Analytic Environment

By Dr. Ann Carbonell, Riverside Research; Bob Gajda, Frontier Enterprise LLC; Johnnie DeLay, L3Harris Technologies; and Alex Fox, Hawkeye 360

The following vignette illustrates a future analysis environment:

The Joint Analysis Center in England alerts the AFRICOM watch desk that Lloyd's of London is reporting three super tankers off the Horn of Africa suddenly going dark as they cease sending Automatic Identification System (AIS) signals. More than six million barrels of oil and at least 75 crewmen are missing. AFRICOM's support analyst, Josephine, calls up the last three hours of AIS signals from the region, isolates the three ships, and plots their courses.

Simultaneously, she queries for radio frequency (RF) intercepts and observes increases in activity before the AIS signals stopped. Geolocation plots show routes intercepting with the tankers, suggesting abnormal and suspicious activity from ocean-based transmitters.

Suspecting pirate activity, Josephine alerts the operations desks and begins exploring

data in her immersive environment. She brings in historical sensor data covering all nearby coastal regions, and she interacts with other analysts from around the world. Much like players in the online video game "Fortnite," these analysts collaborate on analytic approaches and allocate workload to the most appropriate person. Social media analysis algorithms reveal two unusual trends: diminished activity from among identified

"pirate sympathizers" and increased overall chatter from nearby port facilities. Since Josephine has used these tools and data sources many times and knows them to be reliable, she determines that these indicators point to probable locations for intervention.

Coordinating with operations, Josephine requests real-time coverage of the suspected area and downloads recent military, commercial, and historic content to begin building an operational target folder. Her "hyper-dimensional" pattern-of-life tool offers her multiple perspectives that will be useful in operational planning—what "normally" happens in the region, what is "different" right now, and possible weighted scenarios. The race to recover the ships and save the crewmen is on!

Unfortunately, this response scenario is not possible today. Analysts cannot easily, quickly, and reliably reach into the vast set of potential input sources suggested in the vignette above. They cannot fuse collateral sources with conventional reconnaissance and remote sensing sources, or seamlessly interact with dispersed analysis resources through a common immersive interactive framework. Inconsistent data schemas and nonexistent ontologies hamper the few existing fusion and conflation tools. Algorithms and artificial intelligence (AI) tools that sample data and produce products such as trends and anomalies are not widely available, trusted, or used.

"Effective visualization is a key part of the discovery process in the era of 'big data.' It is the bridge between the quantitative content of data and human intuition, and thus an essential component of the scientific path from data, into knowledge and understanding." [1]

Because the vignette's analysis environment does not fully exist today or is incomplete, unintegrated, or unreliable, responsive decisions cannot be made. The result? Lives at risk or lost.

"Instead of improving the world, [biased and unreliable automation tools such as AI/ML] could be making things worse. Not predicting the future; causing the future." [2]

The future is about reliable and responsive decision environments operating across all sensing domains and across the electromagnetic spectrum. These environments bring together three-dimensional (positional x,y,z), four-dimensional (temporal), and five-dimensional (e.g., trends, event durations, and connectedness to other data streams) data characteristics to provide analysts with a holistic perspective. Analysts are enabled by machines that are interoperable, are self-learning, operate as human teammates, are trusted sources of information, and effectively assist in determining decisive action.

What needs to be done to create a more integrated, data-fused and conflated, machine-assisted, and accurate "Cognitive Analytic Environment (CAE);"[3] regardless of sensing domain, an individual system's accuracy and resolution, the medium, or the passage of time? The analytic community must focus on three critical components:

- **Content**: What content is available with its provenance and trustworthiness understood, how readily useful is it, and what needs to be done to more fully utilize the content?

- **Analytics:** What is the maturity of the analytic technology and what issues need to be resolved?

- **Trust:** We must improve our trust in data, algorithms, tools, and analytic products. What influences user trust and how can trust be enhanced?

A Multitude of Sources

As of November 2018, more than 500 U.S. commercial and civil satellites were in orbit,[4] most performing remote sensing operations in diverse segments of the spectrum and observing the world all day, every day. But sensing is not just performed by satellites. For example, state and city departments continuously monitor street life, traffic, and critical infrastructure in support of quality of life. In London alone, there are an estimated 625,000 cameras in use today.[5]

And sensing operations collect more than pictures. RF sensing systems can identify and geolocate emitter activity everywhere on Earth every day—monitoring planes, ships, seismic activity, and weather. Social media content usually includes location and time information, bringing new sources into observation domains and offering incredible potential given the volume of data being generated by their users—a number that is continually rising. Today there are 300 million monthly Twitter users, 900 million Instagram users, and 200 million Snapchat users[6] alone. Open-source data include media items such as news broadcasts, newspaper and magazine articles, and company and government analysis reports.

Remote Sensing (RS) Sources[7] are the most prevalent data, operating across the electromagnetic spectrum, from satellite and airborne platforms, day and night, and in single and multiple bands. With the advent of small satellites and drones, a "virtual constellation" exists, providing near-continuous, worldwide collection potential. Analytic experience with RS systems is robust, albeit not generally integrated with other systems. Data processing is common and geolocation determination accurate and well defined. However, with volume of commercial data overwhelming infrastructures, the notion of bringing all the data to the enterprise becomes cost-

1. C. Donalek, S. Djorgovski, A. Cioc, A. Wang, J. Zhang, E. Lawler, S. Yeh, S. Davidoff, J. Norris, G. Longo, A. Mahabal, M. Graham, and A. Drake. "Immersive and Collaborative Data Visualization Using Virtual Reality Platforms." 2014 IEEE International Conference on Big Data, 609.
2. Cathy O'Neil, author of "Weapons of Math Destruction," quoted from the "*The Secret History of the Future*" podcast from August 14, 2019.
3. The "Cognitive Analytic Environment," or CAE, is a construct proposed by the authors.
4. L. Grego. "*Record Number of Satellites in Orbit.*" https://allthingsnuclear.org/lgrego/2018satellitedata. January 9, 2019.
5. J. Ratcliffe. https://www.cctv.co.uk/how-many-cctv-cameras-are-there-in-london/. May 29, 2109.
6. J. Clement. https://www.statista.com/statistics/545967/snapchat-app-dau/, https://www.statista.com/statistics/282087
J. Clement. https://www.statista.com/statistics/545967/snapchat-app-dau/, https://www.statista.com/statistics/282087/number-of-monthly-active-twitter-users/, https://www.statista.com/statistics/253577/number-of-monthly-active-instagram-users/. August 14, 2019.
7. The authors include GIS and other mapping data as primarily produced from RS sources. Therefore, the authors include them in this source type.

prohibitive, thus putting more emphasis on upstream distributed processing.

While each system's data and metadata formats are unique, there is consistency across products that adhere to standards such as the National Imagery Transmission Format (NITF). This is less the case for metadata content. Accessing the sources is a challenge because vendors maintain their own discovery, processing, and distribution systems as well as their own unique business pricing models.

A significant improvement in the integration of RS source data would be a "data concentrator service" through which issues of availability, access, provenance, formatting, geolocation accuracy, privacy, pricing, and metadata issues could be resolved. For example, "all" electro-optical (EO)— or radar, RF, or multispectral— sources, regardless of platform, would be processed in a consistent manner, output in a common format, and normalized (by time, resolution, quality). The concentrator would handle the sensor- and platform-specific encoding techniques and output to a common standard so software and other application usage would not be constrained by data format issues. For users looking for "one-stop-shopping," the ideal CAE would not have to be a data processing system, and instead would provide more focus on analytic processes.

Sources are usually a mixture of two-dimensional and three-dimensional data with an additional time component. But when the sources are exploited as collections of integrated data, they have inherent five-dimensional, or hyper-dimensional, characteristics. We need to concentrate on conflation and fusion, making the data richer and creating new datasets and thereby moving to the hyper-dimensional data space.

"The more dimensions we can visualize, the higher are our chances of recognizing patterns, correlations, and outliers." [8]

Open-Source Media analysis deepens the analytic potential when analysts integrate existing reports, findings,

assessments, and conclusions on the topic under investigation. The challenges around preparing social media data also exist for open-source media, only amplified. The authors believe that a data concentrator could be applied to this domain. Three prominent examples are already in wide use today: AP News summarizes, collates, and produces data on news events; Bloomberg does the same for financial data markets; and LexisNexis serves business information.

Social Media is the "Wild West" compared to RS sources. Geolocation and time are implied in the data, but not necessarily as a specified data element. Standardized product formats do not exist as they do for imagery, video, and geographical information system outputs. Social media sources are a challenge to use because each vendor is a unique provider.

The biggest challenge to using social media data in a CAE is the lack of product definitions and associated standards. Raster, vector, and data cube formats are well established. The CAE will have to establish needs for this information so appropriate formats can be devised. Once formats are established, a data concentrator model could be developed to handle access, processing, formatting, and delivery of such content.

Key Analytic Capabilities

The CAE looks at situations holistically, operates as a human's teammate, and is trusted. Success starts with driving the configuration from the mission questions and then exploring what we can get out of the data. Today, integration, collaboration, and AI/machine learning (ML) automation research and investment leads from the data and not from the questions being addressed. One could never finish the task of building a CAE for every possible question across all available data. Even when focusing on a specific problem, building the analytic models and conditioning the data is a challenge. A useful CAE needs to be mission-constrained (by topic, region, question, decision intent). A mission constraint

that is too broad will be unmanageable in terms of creating concisely defined analysis models, accessing and understanding relevant data, or building visualizations that explain the data.

Analytic models then must be developed for the specific mission being explored. Taxonomies and ontologies must be developed so data from a concentrator can be indexed, fused, and/or conflated for analyst visualization and consumption. Semantic technologies are at the heart of the future geospatial enterprise systems, with mission-specific ontologies providing the basis to understand human reasoning. Mission-specific ontology will drive the development of cognitive solutions and form the core of AI initiatives.

Within this new paradigm, a semantically enabled CAE will allow systems to understand the way analysts reason and how to connect information for them. Through self-learning, such AI systems will simultaneously bolster a user's ability to understand data and provide the means to discover a whole new world of relationships among the data and entities contained within them. Through the application of semantic technologies, we can consolidate and link widely dispersed information by integrating it into mission-driven knowledge graphs in support of the CAE that can be queried.

The third action needed is to provide a robust immersive environment for user applications, querying, and decision-making, and for collaboration with supporting analysts. Analysis functions include visualization, natural language processing, AI/ML, social media analytics, and "conventional" data analytics.

"Visualization is essential in the data mining process, directing the choice of algorithms, and in helping to identify and remove bad data from the analysis." [9]

The key technical challenge is not simply tools, but rather tools that will work within the appropriate analytic model. The models will direct the tools to the question being asked, and their products

8. *Immersive and Collaborative Data Visualization*, 610.
9. Ibid, 609.

will reflect the on-the-ground situation being provided by the input sources.

"Immersion provides benefits beyond the traditional desktop visualization tools; it leads to demonstrably better perception of datascape geometry, more intuitive data understanding, and a better retention of perceived relationships in the data." [1]

The immersive environment is a fully formed collaboration environment. As long ago as 1982, researchers confirmed that collaborative performance exceeded an individual's performance measure.[2] Effective "sensemaking" is a process of discussion in which interactive visualization supports social interaction."[3] In other words, immersive collaboration, especially via virtual reality technologies, provides for "telepresence" collaboration sharing a common viewpoint or navigating independently.

Trust in the Environment

Analysts must trust the CAE's sources of information and its analytic processes and tools for determining decisive action.

Today's analysis domain is basically a set of linear processes integrated by the user at each step in the process. The analysts have high confidence because they have examined every dataset, requested and reviewed all intermediary products, collated and fused data from collateral sources, and used their judgment on what the data means. Having direct responsibility for each step, analysts *trust* the outcome. They have a "positive relationship" with the data and data providers because there is validated "judgment and expertise," and they have seen "consistent" results over time.[4]

In the future, analysts will be presented with data they have not "touched" and with intermediate analysis products from algorithmic tools that they may not fully understand.

Why do people trust stock market analysis tools? Why do users trust Waze for the best route to their destination? Why do Fantasy Football players rely on opinions from sports experts? How can we create that same kind of trust for the CAE? Not until there is clarity in the "goals" the algorithms are pursuing. Not until the analysts' "expertise" with the system matches their history with former hands-on systems. Not until there is full "transparency" in how the CAE functions. Not unless the analyst participated in "building the environment." And not until the analyst has fully "experimented" with the CAE's processing conditions and values.[5]

Trust in a decision-support tool is critical. In December 2018, Glenn Gaffney, Former Director of the CIA's Science and Technology Directorate, stated, "If we are going to rely on those things [automation, AI, ML, and deep learning] there are some deep questions that need to be addressed … things like explainability of models, and the effect of collection bias and data bias in those models. We are going to have to understand much deeper how they work and what's really happening…."[6]

"Deep fakes," created when audio and video data is manipulated to present false information to a consumer, is a growing concern. Relying on a trusted data concentrator will reduce these risks. The increased evidence of artificially influenced social media data, though, could still bias data from a concentrator. Increasing trust in AI technologies is a key element in accelerating adoption and use across the intelligence and defense communities. Today, the life-cycle management for AI/ML is limited, and there are few ways to measure an algorithm's trustworthiness. AI standards and related tools, along with AI risk management strategies, need to rapidly evolve to address this limitation and spur innovation. For GEOINT analysts to trust AI, they will need to understand data

curation, accuracy, reliability, security, and provenance for the entire life cycle of the data and AI process.

Across the U.S. government, the reliance on AI tools has caused concern. The government has launched an initiative in response to Executive Order 13859[7] to bring standards to AI technologies in order to ensure there is "… public trust, and public confidence in systems that use AI Technologies." A key element recognizes that data standards and datasets in standardized formats, including metadata, are vital to ensuring the data's applicability in making informed decisions. This is especially the case within a hyper-dimensional analytic environment, where accuracy, provenance, reliability, and dependability build trust.

The Way Ahead: A Call to Action

How do we get to a trusted, integrated, collaborative, multisource, accurate, and immersive CAE? First, the government needs to articulate the compelling need for integrated immersive analysis and solicit concepts, ideas, pilots, and prototypes from industry. From these, the government needs to develop road maps across technological boundaries. Then together, industry and government must develop technologies across a wide spectrum of needs. The technologies include:

- **Visualization of multiple dimensions** as a key part of discovering patterns, correlations, and outliers in big data. Collaboration techniques through virtual reality devices should be considered. Immersion provides more intuitive data understanding and better perceived relationships in the data.

- **Development of mission analysis ontologies** with an eye toward the analytic models that will drive AI/ML tools. Mission-specific ontology will drive the development of cognitive solutions and form the core of AI initiatives.

1. Ibid.
2. G. W. Hill. "Group Versus Individual Performance: Are N+1 Heads Better than One?" *Psychological Bulletin.* 91(3):517-539. https://psycnet.apa.org/record/1982-23527-001.
3. J. Heer and M. Agrawala. "Design Considerations for Collaborative Visual Analytics." Proc. IEEE VAST, 2007.
4. J. Zenger and J. Folkman. https://hbr.org/2019/02/the-3-elements-of-trust. February 5, 2019.
5. A. Raymone. https://www.techrepublic.com/article/infographic-7-ways-to-build-trust-in-data-and-analytics-at-your-company/. November 2, 2016.
6. G. Gaffney, quoted from the "*Intelligence Matters*" podcast from December 11, 2018.
7. NIST. "U.S. Leadership in AI: A Plan for Federal Engagement in Developing Technical Standards and Related Tools – Draft for Public Review 2-Jul-2019."

- **Establishment of data schema, data standards, conflation approaches, and indexing methodologies** to develop and advance five-dimensional analytic environments. Approaches to integrate curated, validated, and metadata-complete data with automation tools is crucial.

- **Development of a "data concentrator service" for all forms of sources** that addresses availability, search and discovery, data access, formatting, geolocation accuracy, conflation, and curation. Companies, uniquely or in joint venture, should explore this potential. The authors believe there are business cases supporting such endeavors.

- Finally, the government needs to **continue pursuing standards for automation and AI** per Executive Order 13859. Building trust in analytic outcomes cannot be gained without consistency and transparency. Meanwhile, nontechnical policy and legal issues such as privacy, data rights, and intellectual property protection, as well as liability issues, must be addressed now before their absence creates chaos.

The potential value of a CAE is immense when all relevant data sources are available for analysis and the analysts are collaborating in a common, real-time, and immersive environment. In this environment, tools and algorithms are automatically deployed, providing insights for decisions and analyst feedback, and continuous learning enhances the analytic processes. The human is in full partnership with the environment, forming judgments leading to decisions. ⊝

USGIF

The United States Geospatial Intelligence Foundation (USGIF) was founded in 2004 as a 501(c)(3) non-lobbying, nonprofit educational foundation dedicated to promoting the geospatial intelligence tradecraft and developing a stronger GEOINT Community with government, industry, academia, professional organizations, and individuals who develop and apply geospatial intelligence to address national security challenges.

USGIF executes its mission through its various programs, events, and Strategic Pillars:

Build the Community
USGIF builds the community by engaging defense, intelligence, and homeland security professionals, industry, academia, non-governmental organizations, international partners, and individuals to discuss the importance and power of geospatial intelligence.

Advance the Tradecraft
GEOINT is only as good as the tradecraft driving it. We are dedicated to working with our industry, university, and government partners to push the envelope on tradecraft.

Accelerate Innovation
Innovation is at the heart of GEOINT. We work hard to provide our members the opportunity to share innovations, speed up technology adoption, and accelerate innovation.